

FINAL
QUANTICO WATERSHED STUDY
QUANTICO CREEK ECOLOGICAL AND HUMAN HEALTH
RISK SCREENING ASSESSMENT

Prepared for:



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EXECUTIVE SUMMARY

Quantico Marine Corps Base is located in Northern Virginia, approximately 58 kilometers south of Washington, D.C. The base covers more than 24,000 hectares, and is bordered to the north in part by Quantico Creek, a tributary to the Potomac River. The tidally influenced section of Quantico Creek, which is the focus of this report, extends approximately 4.1 kilometers upstream from the Potomac River, and varies in width from approximately 150 to 900 meters. The Marine Corps Base extends along the south shore of Quantico Creek from its confluence with the Potomac River upstream approximately 2.8 kilometers.

Sediment samples were collected from Quantico Creek in October 2001 as part of a Pilot Study investigation of the Quantico Watershed (Battelle and Neptune and Company, 2001). Data from sixteen sediment samples submitted for fixed laboratory chemical analyses were used in this report to conduct screening-level human health and ecological risk assessments to determine if base operations have impacted Quantico Creek and potentially pose risks to human health or the environment. Concentrations in sediment samples collected adjacent to the Base were compared to concentrations in upstream areas of Quantico Creek outside the influence of Base operations to determine if site concentrations were higher than background conditions for the creek.

Metals data for Quantico Creek showed that aluminum, cadmium, copper, iron, manganese, nickel, selenium, thallium, and zinc were all highest in upstream samples, with concentrations decreasing along a downstream gradient toward the Base. The concentrations of barium, beryllium, arsenic, chromium, cobalt, and silver were generally uniform throughout Quantico Creek, with no increasing or decreasing trends or patterns evident in the sampling locations. Available data indicates that observed concentrations of these metals are likely due to historical mining activities that occurred upstream in Prince William Forest Park. Antimony, lead, and mercury are the only metals that were higher in sediments adjacent to the Base than in upstream sediments, with the highest concentrations of these constituents located near the mouth of Little Creek. However, none of these constituents were statistically significantly different from background conditions in Quantico Creek. Polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), DDx's, and several other pesticides were all higher in downstream sediments than in upstream background sediments, indicating sources somewhere in the vicinity where Little Creek joins Quantico Creek.

A screening-level human health risk assessment was conducted using a recreational use scenario for members of the public and Base community, with the primary activity assumed to be recreational fishing. Potentially complete exposure pathways included ingestion of fish, incidental ingestion of creek sediments, and dermal contact with creek sediments. Fish tissue concentrations were estimated using sediment to fish accumulation factors obtained from the literature (EPA Region 3, 2002), and the estimated concentrations were compared to Region 3 risk based concentrations (RBCs) for fish tissue.

Arsenic and iron were the only chemical constituents that posed potential risk to humans from dermal contact with sediments, with maximum site concentrations exceeding RBC values by factors of three and two, respectively. However, these constituents near the Marine Corps Base are not elevated with respect to ambient conditions in Quantico Creek, and the data indicates that these metals likely originated from upstream mining activities. Among the chemicals with maximum predicted fish tissue concentrations above RBC levels, only PCBs, DDx's, and dieldrin were determined to be present in higher concentrations in sediments adjacent to the Base than in upstream sediments. Fish consumption advisories issued by the Maryland Department of the Environment (MDE) and the Virginia Department of Environmental Quality (VADEQ) for the region already address PCBs and dieldrin. With respect to Quantico Creek, this screening suggests that DDx's in sediments may also be a potential human health concern via a fish ingestion exposure pathway, although given the limited size of Quantico Creek, it is

uncertain whether the DDx concentrations measured in sediments would result in the predicted fish tissue concentrations.

The screening-level ecological risk assessment assessed potential risk to benthic-dwelling fauna exposed to Quantico Creek sediments, and piscivorous birds (great blue heron) and mammals (raccoon) ingesting contaminated prey in Quantico Creek. The initial screening compared maximum sediment concentrations to EPA Region 3 accepted sediment screening benchmarks, and maximum calculated food chain doses to literature based toxicity reference values (TRV). The initial screening was followed by a screening refinement step that considered background conditions in the creek and the modification of exposure estimates to reflect sediment exposures across the site. The screening-level ecological risk assessment and refinement identified the following chemical constituents as COPCs in Base sediments in Quantico Creek: acenaphthene, fluorene, gamma-chlordane, dieldrin, the 4,4'-DDx's, and total PCBs. Of these, only 4,4-DDE posed a potential risk to piscivorous birds. None of these chemicals posed a risk to piscivorous mammals. In addition, no current sources of any of the constituents posing potential risks to human health or ecological receptors have been identified along Quantico Creek from Base activities.

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ACRONYMS AND ABBREVIATIONS

BAF	bioaccumulation factor
BSAF	biota-sediment accumulation factor
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	chemicals of potential concern
COPEC	chemicals of potential ecological concern
CSM	conceptual site model
DL	detection limit
EFACHES	Engineering Field Activity Chesapeake
ER-L	effects range-low
ER-M	effects range-median
HQ	hazard quotients
LOAEL	low observed adverse effect level
MDE	Maryland Department of the Environment
NOAA	National Oceanic and Atmospheric Administration
NOAEL	no observed adverse effect level
NPDES	National Pollutant Discharge Elimination System
NS&T	National Status and Trends
PAH	polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
RBC	risk based concentrations
RCRA	Resource Conservation and Recovery Act
SAV	submerged aquatic vegetation
SUF	site use factor
TPH	total petroleum hydrocarbons
TRV	toxicity reference values
TtNUS	Tetra Tech NUS
UCL	upper confidence limit
USEPA	United States Environmental Protection Agency
VADEQ	Virginia Department of Environmental Quality

1.0 INTRODUCTION

This document presents the results of the screening-level human health and ecological risk assessments for Quantico Creek adjacent to Quantico Marine Corps Base in Northern Virginia. This report has been prepared for Engineering Field Activity Chesapeake (EFACHES) by Battelle and Neptune and Company under Contract Number N47408-01-D-8207.

The data presented in this report was collected as part of the Quantico Watershed Pilot Study conducted in October 2001 (Battelle and Neptune and Company, 2001b) to obtain data on chemical constituent concentrations in sediments in the major flowing water bodies at Quantico Marine Corps Base.

1.1 Purpose and Objectives

The purpose of this document is to present screening-level human health and ecological risk assessments for Quantico Creek. The three primary objectives of the screening-level risk assessments are: 1) to determine if operations at the Marine Corps Base (hereafter referred to as “the Base”) have resulted in the release of chemical constituents to Quantico Creek; 2) to assess, using a conservative screening approach, whether concentrations of chemical constituents related to Base activities occur at concentrations that possibly pose unacceptable risk to humans and ecological receptors; and, 3) to determine whether chemical concentrations present in sediments adjacent to the Base are different from concentrations in upstream sediments that represent background conditions in Quantico Creek.

1.2 Regulatory Context

The Navy has agreed to conduct screening-level human health and ecological risk assessments for Quantico Creek following guidance established by the United States Environmental Protection Agency (USEPA, 1989, 1997) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also known as “Superfund”. Although Superfund guidance is being followed in the conduct of the screening-level risk assessments, no portion of Quantico Creek study area, as defined in this document, falls under the auspices of the Superfund program. Likewise, no portion of the Quantico Creek study area is subject to regulation under the Resource Conservation and Recovery Act (RCRA). The screening-level ecological risk assessments and the evaluation of background data in the risk assessment were conducted in accordance with Navy Policy (Navy 2000).

1.3 Report Organization

This report is organized into seven sections and three appendices. The remaining sections present the available data and the components of the screening-level risk assessment. Section 2 presents the site characterization, including a description of the physical and ecological setting of Quantico Creek, and a summary of Base operations that may have impacted the site, as well as offsite (Non-Marine Corps) operations that may have contributed chemical constituents to Quantico Creek.

Section 3 provides a discussion of nature and extent of contaminants and the data collected from the Pilot Study investigation.

Section 4 presents the conceptual site model for the site, including a discussion of potential sources of chemical constituents and fate and transport mechanisms, and a summary of the relevant human health and ecological exposure scenarios and pathways for Quantico Creek sediments.

Section 5 presents the screening-level human health risk assessment, including the methodology used, the results of comparisons of sediment concentrations to EPA Region 3 human health risk-based concentrations (RBCs), the risk characterization, and uncertainty discussion.

Section 6 presents the screening-level ecological risk assessment that includes a comparison of sediment chemical concentrations to EPA Region 3 sediment screening benchmarks, an evaluation of risk to upper trophic level receptors, a refinement of the screening assessment based upon EPA and EFACHES protocol, and an uncertainty discussion.

Section 7 presents a summary of the conclusions of the human health and ecological risk assessments.

Appendix A presents the data through bubble plots that illustrate the distribution of chemical constituents in Quantico Creek. Appendix B contains supporting information for the screening-level ecological risk assessment, including site visit notes and the basis for the selection of the toxicity reference values used in the ecological food chain modeling. Appendix C contains the data set from the Quantico Watershed Pilot Study that was used in this report.

2.0 SITE CHARACTERIZATION

2.1 Site Setting

Quantico Marine Corps Base is located in Virginia approximately 58 kilometers south of Washington, D.C. The facility covers more than 24,000 hectares in southern Prince William County, northern Stafford County, and eastern Fauquier County. The facility consists of two sections, the Mainside Area (located east of I-95), and the combined training areas (located west of I-95). The Mainside Area is bordered in part on the north by Quantico Creek, which is the focus of this investigation (Figure 2-1).

2.1.1 Physical Setting

Quantico Creek can be divided into two main sections: the tidally influenced lower portion that occurs downstream from the town of Dumfries, and the non-tidally influenced upper portion that occurs upstream from Dumfries and extends west into Prince William Park (Figure 2-2). The tidally influenced section of the creek is the focus of this investigation, because it is this section where any influences from Marine Corps Base activities would be noted. The tidal portion of Quantico Creek extends approximately 4.1 kilometers upstream, and varies in width from approximately 150 to 900 meters. The western one-quarter of the tidal section of Quantico Creek adjacent to the town of Dumfries is marshy in nature, with abundant emergent wetland vegetation (Figure 2-3). The eastern three-quarters of the creek consist of open water averaging 1 to 2 meters in depth and heavily vegetated in areas with the submerged aquatic vegetation (SAV) *Hydrilla* and green algae. The northern shoreline is primarily residential, except for the far western end at Dumfries, which is a mix of light industry, and the far eastern end, that is home to the Possum Point Power Plant operated by Dominion Virginia Power. The Possum Point Power Plant consists of three oil-fired units and two coal-fired units, although the coal-fired units are in the process of being converted to gas-fired. An above ground oil pipeline runs the length of the northern shore of Quantico Creek to the power plant. The industries located at the western edge include a cement plant, boat yard, stone/monument works, truck park, and scrapyard. The south shoreline of Quantico Creek from Dumfries to the Quantico Marine Corps Base boundary is residential.

The northern boundary of Quantico Marine Corps Base lies on the southern shore of Quantico Creek, extending from its confluence with the Potomac River upstream to a point approximately 2.8 kilometers from the creek mouth. The creek adjacent to the base is shallow, averaging between 1 and 2 meters in depth over most of its length. Another creek called Little Creek joins Quantico Creek in an area that is shallow (< 1 meter) and delta-like made up of sands, silts, and abundant organic detritus. Little Creek flows through the Marine Corps Base and empties into Quantico Creek approximately 500 meters upstream of the junction of Quantico Creek with the Potomac River. The Little Creek floodplain is an east-west trending drainage feature that receives water from the northern section of the Marine Corps Base's Mainside, including the town of Triangle, the Marine Corps Base golf course and several residential areas within the Marine Corps Base. Several intermittent stream channels and swales along Little Creek and Quantico Creek receive surface water runoff from the southern ridge adjacent to the floodplain, as well as, runoff generated from the site. Based on the site's shallow topographic gradient, surface water generated at the site will either infiltrate into the underlying substrate or discharge into Little Creek as overland surface flow, or as added stream flow in the intermittent stream channels and swales.

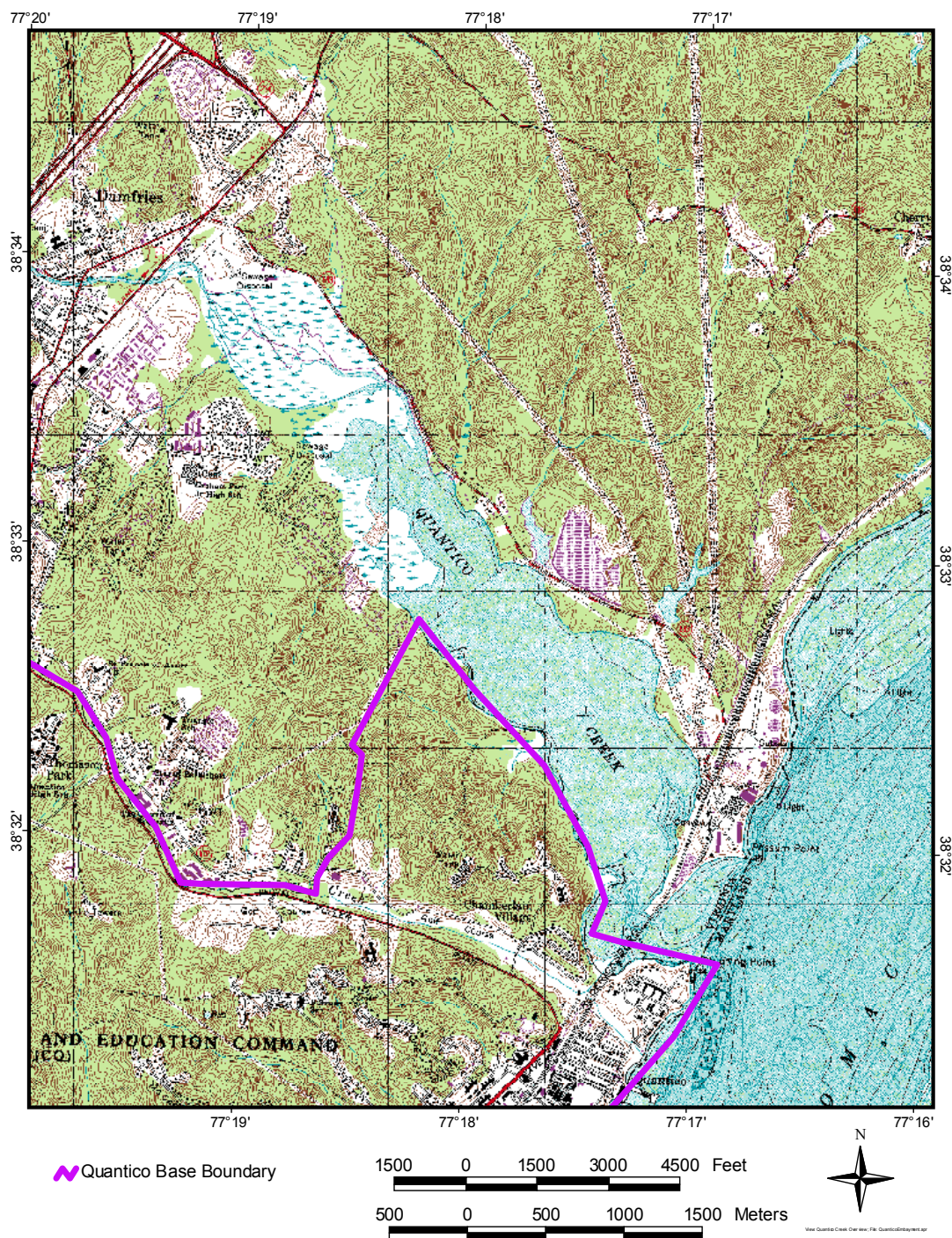


Figure 2-1. Overview Map.

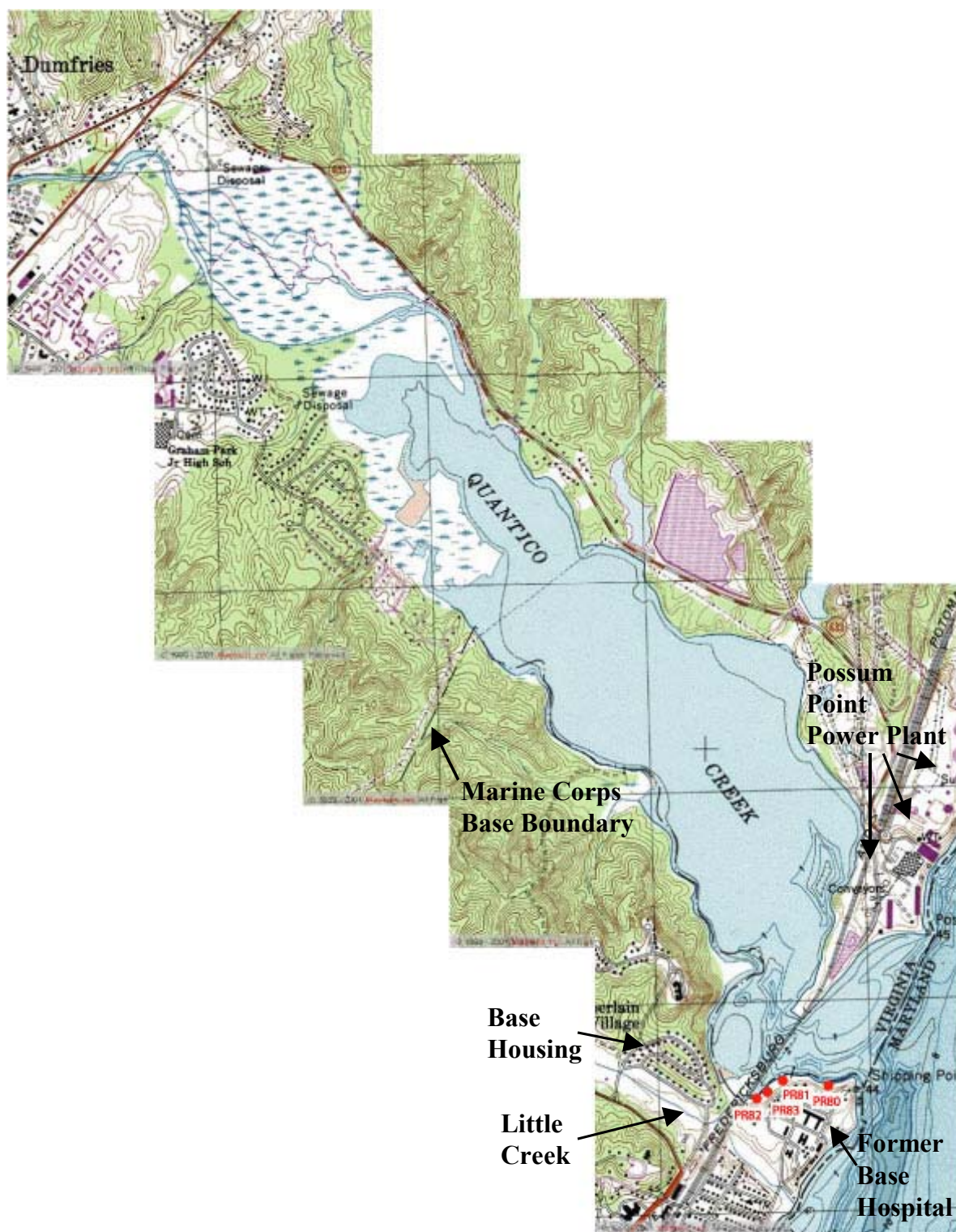


Figure 2-2. Map of Quantico Creek.



Figure 2-3. Photo of Quantico Creek Wetland Area Near Town of Dumfries.

2.1.2 Ecological Setting

The tidal section of Quantico Creek is heavily vegetated throughout its length, with abundant emergent vegetation in the upper portion just downstream from the town of Dumfries. Emergent plants in this marshy area include arrow arum (*Peltandra virginica*), broad-leaved cattail (*Typha latifolia*), willow (*Salix* spp.), and pond lily (*Nuphar* spp.). Hydrilla (*Hydrilla verticillata*) is the most abundant SAV found throughout Quantico Creek.

A wide variety of animals inhabit the Quantico Marine Corps Base. Aquatic mammals documented at Quantico that would utilize Quantico Creek include muskrat (*Ondatra zibethicus*), beaver (*Castor canadensis*), and river otter (*Lutra canadensis*). In addition, terrestrial mammals such as raccoons (*Procyon lotor*) and skunks (*Mephitis mephitis*) will forage along shorelines and in wetland areas of Quantico Creek. Birds found on Quantico Creek include osprey (*Pandion haliaetus*), bald eagle (*Haliaeetus leucocephalus*), and a variety of herons, egrets, ducks, and gulls.

Fish found in Quantico Creek are typical of those in other major tributaries in the transition zone of the Potomac River. These include alewife (*Alosa pseudoharengus*), mummichog (*Fundulus heteroclitus*), blueback herring (*Alosa aestivalis*), striped bass (*Roccus saxitalis*), carp (*Cyprinus carpio*), brown bullhead (*Ictalurus nebulosus*), channel catfish (*Ictalurus punctatus*), and American eel (*Anguilla rostrata*). The brackish water clam *Rangia cuneata* also occurs in Quantico Creek.

Species of special concern, including threatened and endangered species, that have been documented at Quantico Marine Corps Base and that may utilize Quantico Creek include the Bald Eagle (*Haliaeetus*

leucocephalus), Least Bittern (*Ixobrychus exilis*), and the aquatic plant Carolina fanwort (*Cabomba caroliniana*). Bald eagles nest along the Potomac River and forage the length of the river and its larger tributaries. Least bitterns are not federally endangered, but are considered to be a species of concern in Virginia. They forage and nest in areas of thick emergent vegetation such as that found in the marshy areas of Quantico Creek downstream from the town of Dumfries. Carolina fanwort is listed as critically endangered by the Commonwealth of Virginia.

2.2 Operational History

2.2.1 Quantico Marine Corps Base Activities and Sources

Most Marine Corps Base operations that may have impacted Quantico Creek occurred near the confluence of Quantico Creek with the Potomac River along the first 500 meters of shoreline. There are four direct outfall sources from the Quantico Marine Corps Base to Quantico Creek. The four outfalls (PR-80, PR-81, PR-82, PR-83) discharge into Quantico Creek near its confluence with the Potomac River (see Figure 2-2). The outfalls do not have National Pollutant Discharge Elimination System (NPDES) permits and are part of the base storm drainage system. Outfall PR-81 primarily received storm water from roof drains and air conditioning condensate overflows¹ associated with the former base hospital. Outfall PR-82 also drained storm water from the former pathological incinerator of the base hospital. Outfall PR-82 was also potentially influenced by runoff from Site 35, a former drum storage area and Site 58, an area of oily stained soil discussed below. Outfalls PR-80 and PR-83 have been observed in the local area but information regarding their function has not been documented. It is questionable if these two outfalls continue to function, as the last outfall map revision dated August 1975 (1959 original edition) did not indicate a drainage area.

Two Marine Corps Base sites that could have impacted Quantico Creek are Site 35, also known as Building 2208 Accumulation Area, and Site 58, a stained patch of ground located approximately 50 yards north-northwest of Building 2208. These sites are located near the confluence of Little Creek and Quantico Creek. Site 35 was a small 2-foot by 2-foot drum storage area that was located along the southern exterior wall of Building 2208. A drum containing Univolt 60 transformer oil was located in this storage area, and a large stain was observed on the soil underneath the drum. Site 58 covers approximately 60 square feet and contains darkened soils with an oily texture and odor. The source and type of the oil is unknown. Drainage characteristics from both sites are relatively flat with a slight northwesterly dip (*i.e.*, a 10 to 15 foot drop) towards Quantico Creek. Based on topography of the area, surface water runoff generated from the site discharges to Quantico Creek as overland surface flow. Quantico Creek lies approximately 100 meters northwest of the site. Groundwater is suspected to flow generally to the north, mirroring the local topography and reflecting the influence of Quantico Creek. Site 35 appears to have been graded relatively flat during the demolition and removal of Building 2208. The area recently graded has been blended to match the local topography and has been recently reseeded. No sign of the former building or drum storage area was observed during the recent ecological assessment site visit. Both Site 35 and Site 58 have been closed with no further action as part of the final Desktop Audit with Sampling (DTAWS) Report #2 (TtNUS, September 2000a) that was signed on July 10, 2001. The DTAWS report determined that these sites are not current contributing sources to Quantico Creek.

Although no outfalls flow directly into Little Creek, activities occurred along Little Creek that could have had impacts on Quantico Creek. Site 14, a construction debris landfill that operated from 1917 to 1920, is located between Little Creek and Fuller Road near the 10th green of the base golf course. The landfill was used to dispose of Quantico Marine Corps Base construction debris. There are no reports of hazardous wastes being disposed of at the site and significant hazardous chemical releases are unlikely given the

¹ Personal communication with Mr. Chuck Grimes, Quantico Marine Corps Base Environmental Office 7/19/01.

timeframe of operation and type of waste disposal. The landfill was reportedly closed because it was clogging the creek (NEESA, March 1984). A 1994 field inventory showed no evidence of contamination, but in recent site visits by Tetra Tech NUS (TtNUS, 2000b) in January and March 1998, there was evidence of construction debris along the edges of the creek. Site 98 is a golf course maintenance area in the Little Creek watershed that is the subject of an investigation by TtNUS planned for the summer of 2002. Activities that occurred at Site 98 included mixing of pesticides for application to the golf course.

Immediately to the east (downstream) of the mouth of Little Creek, a railroad bridge crosses Quantico Creek. Passenger and freight trains frequently use this concrete bridge. Just to the east of the railroad bridge is a small boat launch and wooden fishing pier. From the mouth of Little Creek upstream to the Base boundary on Quantico Creek, the area is primarily undisturbed, with some Base residential areas. No outfalls occur in this area, and any impacts to Quantico Creek would be from non-point-source runoff from the residential areas and the Base golf course located a short distance inland along Little Creek.

2.2.2 Offsite Activities and Sources

A number of sources of chemical constituents not associated with Quantico Marine Corps Base have also potentially impacted Quantico Creek. The most significant of these sources is historical mining activities along the upper non-tidal portion of Quantico Creek. The Cabin Branch Mine of Prince William County, VA was in operation from the 1890's until it was abandoned in the 1920's. The mine lies along the non-tidal portion of Quantico Creek approximately 2.4 kilometers northwest of the town of Dumfries. The Cabin Branch mine was mined for its sulfur, copper, zinc, and lead, but also yielded gold and silver as byproducts. Another mine, the Greenwood Gold Mine, is located upstream of the Cabin Branch Mine near the head of the North Fork of Quantico Creek. This mine was identified as a source of mercury contamination (Seal *et al.*, 1998). Both mines are located in what is now Prince William Forest Park, a unit of the National Park Service.

The Cabin Branch mine site was a known cause of environmental and safety problems throughout the 1900's. These problems included unvegetated mine tailings along Quantico Creek, acid producing pyretic materials on the creek bank and in the creek sediments, open shafts, and old process areas. The water quality in Quantico Creek was contaminated with heavy metals, and also had low pH, high conductivity, and significant sediment loading (EPA, 2002).

In 1995, the National Park Service and the Virginia Department of Mines, Minerals, and Energy remediated the area. The reclamation included constructing a storm-water diversion trench around the abandoned mine area, grading the tailings away from the stream bank, adding pulverized limestone and topsoil, and revegetation. After a two-year monitoring program of the water quality, it was confirmed that the levels of copper, zinc, and iron in the surface water have been reduced (EPA, 2002), but no attempts have been made to remediate downstream sediments impacted by mine runoff.

The towns of Dumfries (population 4,659) and Triangle (population 4,740) are located along Quantico Creek and are potential sources of chemical constituents to the creek. The western edge of Quantico Creek is a mix of residential and light industrial activities. Industries neighboring the creek include a cement plant, a boat yard, a stone/monument works, truck park, and a scrapyard. The Possum Point Power Plant is located on the north shore of Quantico Creek at its confluence with the Potomac River. This Power Plant contains both coal and oil fired units.

The Potomac River is a potential source of chemical constituents to Quantico Creek, as tidal mixing moves water and suspended sediment from the Potomac River into the lower portions of Quantico Creek. PCBs and dieldrin have been recognized as chemicals of regional concern in the Potomac River, and the State of Maryland has issued fish consumption advisories due to the presence of PCBs and dieldrin in

certain species of bottom-dwelling fish in this section of the Potomac River. The Potomac River may also be a source of PAHs to Quantico Creek, due to the nature of industrial activities (a power plant and an asphalt plant) that occur just up-river from the mouth of Quantico Creek. No data is currently available to evaluate potential PAH contributions from the Potomac River to Quantico Creek.

It is evident from the above discussion that a variety of Base-related and offsite activities have had the potential to impact Quantico Creek. However, with the exception of the historical mining activities, no information is available that identifies specific releases to the creek that may be responsible for the specific chemical constituents observed in sediments. Additional discussion of possible sources and movement of chemicals within Quantico Creek is presented in the conceptual site model (CSM) in Section 4.

3.0 NATURE AND EXTENT

3.1 Summary of Investigations

Data being used in this report were collected during the Quantico Watershed Pilot Study in October 2001 (Battelle and Neptune and Company, 2001). During that study, twenty-one surface sediments were collected from Quantico Creek using a boat and a petite ponar grab sampler. Surface samples were collected from the top 5 cm to ensure that the sediments represented the biologically active zone. A map of sediment sampling locations is presented in Figure 3-1. Sediment was collected from thirteen Quantico Creek locations adjacent to the Base and eight sampling locations located in Quantico Creek upstream from the Base that were intended to represent conditions in the creek outside the influence of the Quantico Marine Corps Base. Of the thirteen Base samples, eight were submitted for fixed laboratory analyses and rapid analytical analyses, and five analyzed only using the rapid analytical analyses. All eight of the samples representing off-site conditions were submitted for fixed laboratory analyses and rapid analytical analyses. Only fixed laboratory data were used to evaluate risks to human health and ecological receptors. All fixed laboratory samples from Quantico Creek were measured for analytes identified as chemical constituents of potential concern for the Quantico Watershed Study based on historical data from the Potomac River and Chopawamsic Creek, and an evaluation of potential sources of chemical constituents that may have migrated to the creek. A list of chemical constituents included in the analyses is presented in Table 3-1. Although no historical data were available for Quantico Creek prior to this Pilot Study, it was assumed that the list of chemical constituents present in Quantico Creek would be more restricted than other water bodies at Quantico Marine Corps Base because fewer historical Base operations potentially impacted Quantico Creek. All fixed laboratory analyses were conducted using National Oceanic and Atmospheric Administration (NOAA) National Status and Trends (NS&T) methodologies to achieve adequate detection limits for conducting the screening level risk assessments. Additional information on the analytical methods is provided in the Quantico Watershed Pilot Study Work Plan (Battelle and Neptune, 2001).

3.2 Data Summary

Summary tables showing the number of detects and the minimum, maximum, mean, and median concentrations of chemical constituents in Quantico Creek sediments adjacent to the Base, as well as in upstream sediments reflecting Quantico Creek background conditions, are presented in Tables 3-2 through 3-5. The complete data set is presented in Appendix C. Pesticides that were not detected in either site or background samples are not included in the Table 3-5, but are presented in Appendix C. Visual and statistical background examination of the data for metals leads to the conclusion that most metals in sediment are the result of historical upstream mining activities and not from Base activities. Examination of metals concentrations shows that aluminum, cadmium, copper, iron, manganese, nickel, selenium, thallium, and zinc all are higher in upstream samples than in downstream samples. Bubble plots for these constituents (see Appendix C) show all of these constituents decreasing in concentration along a downstream gradient, with lowest concentrations occurring adjacent to the Base. Barium, beryllium, arsenic, chromium, cobalt, and silver are all rather uniform in concentration throughout Quantico Creek, and the bubble plots show no increasing or decreasing trends or patterns are evident for these constituents across sampling locations. Antimony, lead, and mercury are the only metals that are higher in downstream sediments than in upstream sediments, with the highest concentrations of these constituents located near the mouth of Little Creek. Bubble plots illustrating the distribution of all metals in Quantico Creek sediments are presented in Appendix A. Polycyclic aromatic hydrocarbons (PAHs), DDxs, alpha-chlordane, gamma-chlordane, gamma-BHC, and dieldrin were all higher in downstream sediments than in upstream background sediments, indicating sources somewhere in the vicinity where Little Creek joins Quantico Creek. Likewise, aldrin, which was not detected in background sediments

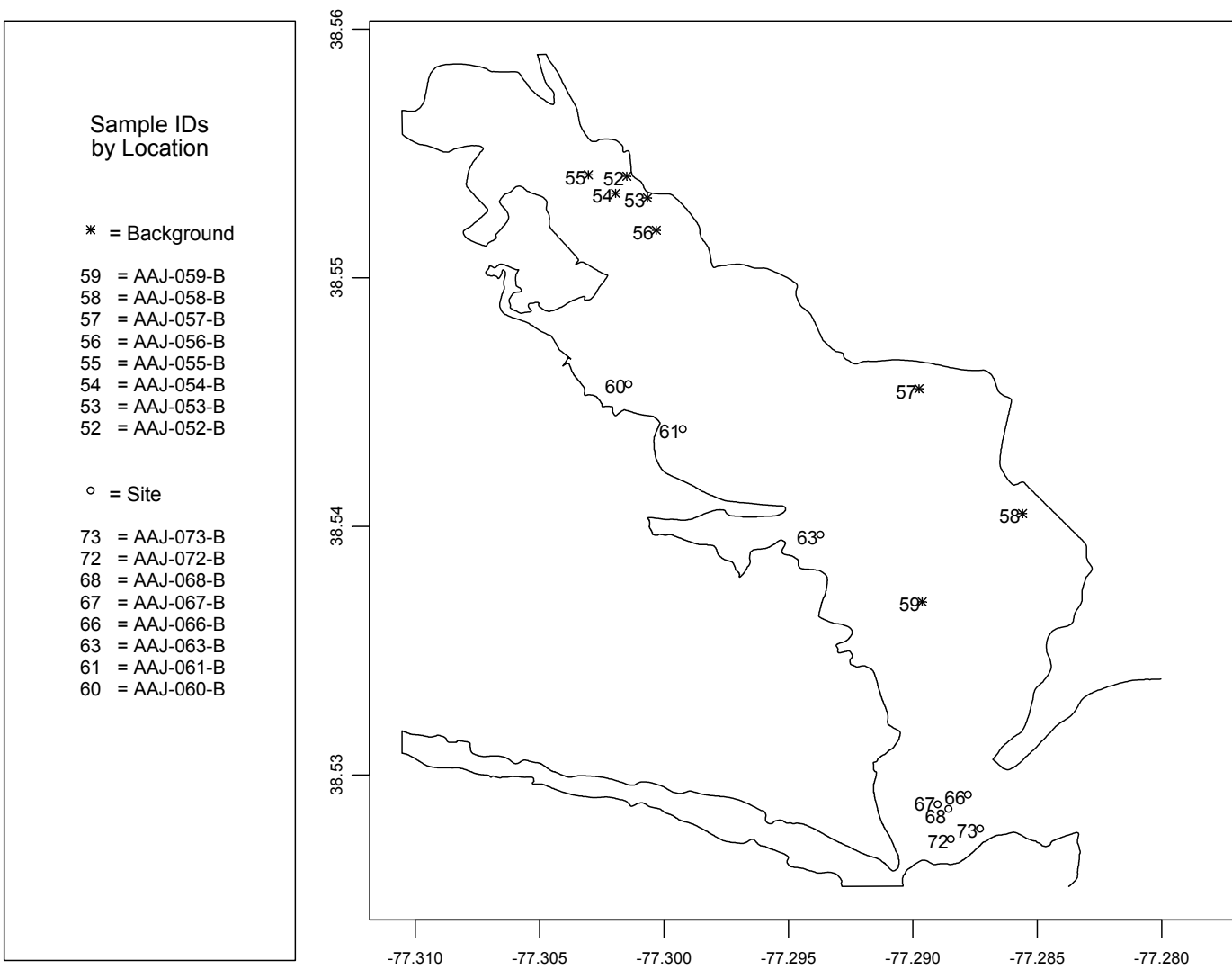


Figure 3-1. Background and Site Locations and Sample Ids of Fixed Laboratory Sample Locations.

Table 3-1. Chemical Analyses Conducted on Quantico Creek Sediments.

Metals	PAHs	Pesticides	PCBs
Aluminum	2-Methylnapthalene	2,4-DDD	Aroclor-1016
Antimony	Acenaphthene	4,4-DDD	Aroclor-1221
Arsenic	Acenaphthylene	2,4-DDE	Aroclor-1232
Barium	Anthracene	4,4-DDE	Aroclor-1242
Beryllium	Benzo(a)anthracene	2,4-DDT	Aroclor-1248
Cadmium	Benzo(a)pyrene	4,4-DDT	Aroclor-1254
Chromium	Benzo(b)fluoranthene	Aldrin	Aroclor-1260
Cobalt	Benzo(g,h,i)perylene	Alpha-BHC	PCB-08
Copper	Benzo(k)fluoranthene	Beta-BHC	PCB-18
Lead	Chrysene	Delta-BHC	PCB-28
Manganese	Dibenzo(a,h)anthracene	Gamma-BHC	PCB-44
Mercury	Fluoranthene	Alpha-chlordane	PCB-52
Nickel	Fluorene	Gamma-chlordane	PCB-66
Selenium	Indeno(1,2,3-cd)pyrene	Dieldrin	PCB-101
Silver	Naphthalene	Endosulfan I	PCB-105
Thallium	Perylene	Endosulfan II	PCB-118
Zinc	Phenanthrene	Endrin	PCB-128
	Pyrene	Heptachlor	PCB-138
		Heptachlor Epoxide	PCB-153
		Methoxychlor	PCB-170
		Mirex	PCB-180
		Toxaphene	PCB-187
			PCB-195
			PCB-206
			PCB-209

Table 3-2. Summary of Fixed Laboratory Analyses of Sediment Metal Concentrations.

Analyte	General Area	Area	N	Nondetects (mg/kg dry weight)		Detects (mg/kg dry weight)				
				n	DL	n	Min.	Median	Mean	Max.
Aluminum	Quantico Creek	Bckgrd	8	0		8	43300	78650	70750	80800
		MCB	8	0		8	39600	68300	62710	76400
Antimony	Quantico Creek	Bckgrd	8	0		8	0.614	0.9185	0.9825	1.41
		MCB	8	0		8	0.548	0.8815	1.566	6.49
Arsenic	Quantico Creek	Bckgrd	8	0		8	6.54	10.95	10.76	13.9
		MCB	8	0		8	5.41	10.41	9.735	13.2
Barium	Quantico Creek	Bckgrd	8	0		8	558	595.5	596.4	646
		MCB	8	0		8	520	553.5	562	598
Beryllium	Quantico Creek	Bckgrd	8	0		8	1.31	2.735	2.446	2.93
		MCB	8	0		8	1.69	2.405	2.259	2.83
Cadmium	Quantico Creek	Bckgrd	8	0		8	0.739	1.435	1.628	2.75
		MCB	8	0		8	0.456	0.9305	1.221	2.74
Chromium	Quantico Creek	Bckgrd	8	0		8	38.1	82.95	75.4	88.1
		MCB	8	0		8	47.7	77.2	70.24	83.3
Cobalt	Quantico Creek	Bckgrd	8	0		8	12.9	29.75	27.38	32.5
		MCB	8	0		8	16.2	28.1	25.79	32.4
Copper	Quantico Creek	Bckgrd	8	0		8	81.1	193	187	254
		MCB	8	0		8	46.1	93.95	120.5	229
Iron	Quantico Creek	Bckgrd	8	0		8	25600	46250	42100	48660
		MCB	8	0		8	23960	43000	38500	45560
Lead	Quantico Creek	Bckgrd	8	0		8	27.7	50.8	48.04	57.8
		MCB	8	0		8	45.9	53.65	61.16	122
Manganese	Quantico Creek	Bckgrd	8	0		8	542	878.5	1040	2030
		MCB	8	0		8	604	972.5	968.4	1210
Mercury	Quantico Creek	Bckgrd	8	0		8	0.0605	0.187	0.1861	0.285
		MCB	8	0		8	0.117	0.2475	0.2357	0.364
Nickel	Quantico Creek	Bckgrd	8	0		8	25.7	55.25	51.46	67.4
		MCB	8	0		8	24.6	50.25	46.39	66.6
Selenium	Quantico Creek	Bckgrd	8	0		8	1.24	3.125	3.334	5.94
		MCB	8	0		8	0.668	0.88	1.42	3.27
Silver	Quantico Creek	Bckgrd	8	0		8	0.26	0.689	0.6482	0.973
		MCB	8	0		8	0.325	0.698	0.6694	1.07
Thallium	Quantico Creek	Bckgrd	8	0		8	0.74	0.9565	1.008	1.35
		MCB	8	0		8	0.565	0.805	0.8239	1.13
Zinc	Quantico Creek	Bckgrd	8	0		8	227	478.5	484.5	732
		MCB	8	0		8	134	331.5	383.6	785

N = total number of samples

n = number of samples within category of detected concentrations or nondetects

DL = reported detection limits

Table 3-3. Summary of Fixed Laboratory Analyses of Sediment PAH Analyte Concentrations.

Analyte	General Area	Area	N	Nondetects (µg/kg dry weight)		Detects (µg/kg dry weight)				
				n	DL	n	Min.	Median	Mean	Max.
2-Methylnaphthalene	Quantico Creek	Bckgrd	8			8	4.2	8.245	11.14	24.25
		MCB	8			8	7.54	12.57	19.37	37.46
Acenaphthene	Quantico Creek	Bckgrd	8			8	2.19	2.82	2.93	3.98
		MCB	8			8	1.67	6.135	8.249	24.78
Acenaphthylene	Quantico Creek	Bckgrd	8			8	0.42	0.89	1.506	6.24
		MCB	8			8	0.47	1.435	2.396	5.32
Anthracene	Quantico Creek	Bckgrd	8			8	3.88	6.185	6.5	10.28
		MCB	8			8	2.93	13.31	19.52	40.43
Benzo(a)pyrene	Quantico Creek	Bckgrd	8			8	19.78	32.02	53.07	197.2
		MCB	8			8	13.06	79.84	95.75	247.5
Benzo(b)fluoranthene	Quantico Creek	Bckgrd	8			8	31.43	49.23	68.16	207.2
		MCB	8			8	21.34	116.8	123.1	278.1
Benzo(g,h,i)perylene	Quantico Creek	Bckgrd	8			8	17.73	25.72	37.17	114.3
		MCB	8			8	9.54	63.33	62.13	139.9
Benzo(k)fluoranthene	Quantico Creek	Bckgrd	8			8	26.44	45.84	67.54	228.1
		MCB	8			8	18.81	105.2	116.1	267.8
Chrysene	Quantico Creek	Bckgrd	8			8	35.35	53.34	71.96	200.8
		MCB	8			8	25.67	134.8	155.3	356.5
Dibenz(a,h)anthracene	Quantico Creek	Bckgrd	8			8	2.95	4.24	7.721	29.56
		MCB	8			8	1.69	11.74	13.62	36.81
Fluoranthene	Quantico Creek	Bckgrd	8			8	69.15	93.04	106.4	204.5
		MCB	8			8	43.52	237	261.1	554
Fluorene	Quantico Creek	Bckgrd	8			8	5.1	7.52	8.616	13.34
		MCB	8			8	5.85	14.06	18.04	38.25
Indeno(1,2,3-c,d)pyrene	Quantico Creek	Bckgrd	8			8	15.44	23.48	38.3	133.6
		MCB	8			8	7.9	60.45	62.15	152.1
Naphthalene	Quantico Creek	Bckgrd	8	5	4.79-9.11	3	13.12	13.84	14.95	17.89
		MCB	8	2	7.87-9.94	6	10.62	20.04	24.05	49.1
Phenanthrene	Quantico Creek	Bckgrd	8			8	26.66	31.38	36.33	58.14
		MCB	8			8	17.94	87.66	90.55	203
Pyrene	Quantico Creek	Bckgrd	8			8	59.03	84.16	101.2	220.7
		MCB	8			8	39.4	204	237	525.6

N = total number of samples

n = number of samples within category of detected concentrations or nondetects

DL = reported detection limits

Table 3-4. Summary of Fixed Laboratory Analyses of Sediment Total PAHs, PCBs, and DDxs.

Analyte	General Area	Area	N	Detects (µg/kg dry weight)				
				n	Min.	Median	Mean	Max.
Total PAHs	Quantico Creek	Background	8	8	488.5	882.7	1043	1940
		MCB	8	8	411.5	1529	1800	3478
Total PCBs	Quantico Creek	Background	8	8	8.94	18.75	21.06	35.62
		MCB	8	8	27.84	36.56	39.81	65.16
Total DDx	Quantico Creek	Background	8	0	1.59	3.335	4.56	10.13
		MCB	8	0	6.11	42.3	54.13	161.7

N = total number of samples

n = number of samples within category of detected concentrations or nondetects

Table 3-5. Summary of Fixed Laboratory Analyses of Sediment Pesticide Analyte Concentrations.

Analyte	General Area	Area	N	Nondetects (µg/kg dry weight)		Detects (µg/kg dry weight)				
				n	DL	n	Min.	Median	Mean	Max.
a-Chlordane	Quantico Creek	Background	8	0		8	0.13	0.305	0.3213	0.53
		MCB	8	0		8	0.21	0.43	0.7313	2.66
g-Chlordane	Quantico Creek	Background	8	7	0.1-0.14	1	0.51	0.51	0.51	0.51
		MCB	8	7	0.08-0.17	1	3.56	3.56	3.56	3.56
gamma-BHC	Quantico Creek	Background	8	5	0.07-0.11	3	0.13	0.16	0.17	0.22
		MCB	8	2	0.07-0.14	6	0.11	0.2	0.1967	0.3
Aldrin	Quantico Creek	Background	8	8	0.07-0.11	0				
		MCB	8	5	0.09-0.13	3	0.19	0.38	0.84	1.95
Dieldrin	Quantico Creek	Background	8	7	0.1-0.17	1	0.33	0.33	0.33	0.33
		MCB	8	3	0.17-0.21	5	0.36	0.79	1.38	4.32

N = total number of samples

n = number of samples within category of detected concentrations or nondetects

DL = reported detection limits

was detected in downstream Base sediments. The exact source(s) of these chemicals in this area is uncertain. Polychlorinated biphenyl (PCB) concentrations are fairly uniform along the south shore and in the three furthest downstream reference location samples, but decrease in concentrations in the five upstream reference samples adjacent to the upstream reference area.

3.2.1 Comparison of Marine Corps Base Sediments to Upstream Background Conditions

Sediment concentrations in Base sediments (*i.e.*, “site” sediments) were compared to concentrations in upstream sediments in Quantico Creek (*i.e.*, “background”) to determine if site concentrations were elevated compared to background, indicating a potential Base source. No metals had site concentrations that were significantly different from upstream reference/background conditions. Even though antimony, lead, and mercury appeared somewhat elevated in sediments adjacent to the Base than in upstream sediments, concentrations were not elevated enough to fail any of the four background comparison tests outlined below. Gamma-BHC failed the statistical comparison because there were an inadequate number of detectable concentrations to run all of the statistical tests. Therefore, if any one of the statistical tests could not be run, then that constituent is listed as “Fail”. Total PCBs failed all four background/reference comparison tests, indicating that site concentrations are significantly different from background conditions in Quantico Creek. Total PAHs did not fail the reference/background comparisons, but several individual PAH analytes failed. Acenaphthene, anthracene, fluoranthene, fluorene, phenanthrene, and

pyrene all failed one or more of the background comparison tests, indicating a possible source of the constituents downstream in the vicinity of Little Creek, the railroad bridge, and the boat launch and fishing pier. The exact source of these constituents in site sediments is uncertain. Site concentrations of Total DDxs were also elevated compared to upstream reference/background sediments. Complete results of the background/reference comparison tests are presented in Table 3-6. In Quantico Creek, site concentrations were deemed to be different from reference/background concentrations if any one of the four statistical tests failed.

Instead of comparing individual site (down gradient) concentrations to a single screening or threshold value calculated from a background (up gradient) data set, distribution shift tests compare site data to the entire distribution of reference/background concentrations. A distribution shift test is used to determine whether site data are systematically greater than reference data. Several types of distribution shift tests are available. The result of performing each statistical test on two data sets (one that represents reference/background and one that represents the site) is a test statistic and an associated significance level (also known as a p-value). The significance level is the probability that the test statistic would be as large or larger than the one produced, if the two data sets were from the same distribution (both were from the reference distribution). A small significance level indicates that it is not likely that the two data sets came from the same distribution. It is standard amongst statisticians to consider “small” to be less than 0.05 (*i.e.*, such a large test statistic would occur by chance less than one out of 20 times when the sampled populations are the same).

Four statistical tests were performed: the t-test (Gilbert, 1987), Gehan test (Gehan, 1965), quantile test (Gilbert and Simpson, 1992), and slippage test (Gilbert and Simpson, 1990). The tests used to conduct the background comparisons are those recommended in the Navy guidance for evaluation of background data (NAVFAC Engineering Command, 1998). The t-test and Gehan test are best suited for assessing complete shifts (of central location) in the distributions. The t-test tests equality of the two population means and the Gehan test tests equality of the two population medians. The Quantile test is better suited for assessing shifts of a subset (upper tail) of the distributions. If the differences between two distributions appear to occur far into the tails, a nonparametric test called the slippage test is performed.

Table 3-6. Results of Background Comparison Tests for Chemical Constituents in Quantico Creek Sediment.

Analyte	Ref	Site	Test Conclusion	P-values of Background Comparison Tests			
	N	N		Gehan	Quantile	Slippage	t-test
Aluminum	8	8	Pass	0.967	1.000	1.000	0.979
Antimony	8	8	Pass	0.682	0.962	0.500	0.160
Arsenic	8	8	Pass	0.785	0.715	1.000	0.501
Barium	8	8	Pass	0.986	1.000	1.000	1.000
Beryllium	8	8	Pass	0.887	0.962	1.000	0.953
Cadmium	8	8	Pass	0.905	0.962	1.000	0.968
Chromium	8	8	Pass	0.959	1.000	1.000	0.944
Cobalt	8	8	Pass	0.800	0.962	1.000	0.945
Copper	8	8	Pass	0.967	0.962	1.000	0.998
Lead	8	8	Pass	0.135	0.715	0.233	0.154
Manganese	8	8	Pass	0.479	1.000	1.000	0.812
Mercury	8	8	Pass	0.282	0.715	0.500	0.549
Nickel	8	8	Pass	0.865	0.715	1.000	0.966
Selenium	8	8	Pass	0.991	1.000	1.000	0.985
Silver	8	8	Pass	0.396	0.715	0.500	0.674
Thallium	8	8	Pass	0.958	0.962	1.000	0.994
Zinc	8	8	Pass	0.841	0.715	0.500	0.987
Total PCBs	8	8	Fail	0.007	0.038	0.038	0.018
Total PAHs	8	8	Pass	0.064	0.285	0.100	0.306
2-Methylnaphthalene	8	8	Pass	0.052	0.285	0.100	0.131
Acenaphthene	8	8	Fail	0.026	0.038	0.013	0.015
Acenaphthylene	8	8	Pass	0.114	0.285	1.000	0.475
Anthracene	8	8	Fail	0.052	0.038	0.013	0.016
Benz(a)anthracene	8	8	Pass	0.215	0.285	0.100	0.279
Benzo(a)pyrene	8	8	Pass	0.282	0.285	0.500	0.416
Benzo(b)fluoranthene	8	8	Pass	0.282	0.285	0.500	0.360
Benzo(g,h,i)perylene	8	8	Pass	0.318	0.285	0.500	0.408
Benzo(k)fluoranthene	8	8	Pass	0.282	0.285	0.500	0.436
Chrysene	8	8	Pass	0.186	0.285	0.100	0.248
Dibenz(a,h)anthracene	8	8	Pass	0.318	0.285	0.500	0.377
Fluoranthene	8	8	Fail	0.135	0.038	0.038	0.079
Fluorene	8	8	Fail	0.020	0.038	0.038	0.070
Indeno(1,2,3-c,d)pyrene	8	8	Pass	0.318	0.285	0.500	0.431
Naphthalene	8	8	Pass	0.052	0.285	0.100	0.086
Perylene	8	8	Pass	0.479	0.715	0.500	0.798
Phenanthrene	8	8	Fail	0.052	0.038	0.038	0.020
Pyrene	8	8	Fail	0.114	0.038	0.038	0.122
4,4-DDD	8	8	Fail	0.003	0.038	0.003	0.142
4,4-DDE	8	8	Fail	0.001	0.038	0.003	0.018
4,4-DDT	3	5	Fail	NA	0.038	0.013	NA
Total DDT (six isomers)	8	8	Fail	0.002	0.100	0.003	0.032
a-Chlordane	8	8	Pass	0.186	0.100	0.100	0.199
gamma-BHC	3	6	Fail	NA	0.285	0.500	NA
Dieldrin	1	5	Fail	NA	0.038	0.013	NA

Ref = reference area up gradient of Quantico Marine Corps Base

Site = site area adjacent to Quantico Marine Corps Base

N = number of detects (out of eight samples in each area)

Fail = the test conclusion equals "Fail" if any value for any test is less than 0.05

NA = test could not be performed due to inadequate number of detects

4.0 PROBLEM FORMULATION

This section presents the initial CSM and the human health and ecological exposure scenarios for the Quantico Creek screening-level risk assessments.

4.1 Conceptual Site Model

The initial CSM for Quantico Creek includes an evaluation of potential current and historical sources of chemical constituents to the creek, and a general discussion of the fate and transport of chemical constituents in the creek, including physical and biotic transport pathways.

4.1.1 Sources

4.1.1.1 Sources of Chemical Constituents to Quantico Creek

There are a number of potential operations, both Base related and non-Base related, that could have impacted sediments in Quantico Creek. These include four direct outfalls, three IR sites (*i.e.*, Site 35 Drum Storage, Site 58 Stained Soil, and Site 14 Landfill), a pesticide mixing area, historical mining activities, an electrical power plant, non-point source surface water runoff, and tidal influx from the Potomac River. These potential sources and associated chemical constituents were discussed in Section 2.2 and are summarized in Table 4-1. Potential chemical constituents associated with these areas are PAHs from storm runoff and metals such as aluminum and copper from building cooling discharges, pesticides (dieldrin, chlordane, DDT) contributed from the mixing area via Little Creek, and cadmium, copper, iron, manganese, selenium, and zinc from the historical mining activities. The Potomac River serves as a potential source of PCBs and pesticides to Quantico Creek because these constituents are recognized as a regional issue for the Potomac River (*i.e.*, fishing consumption advisory). PAHs may be a local issue in the Potomac River due to contributions from upstream industrial activities.

Table 4-1. Summary of Potential Sources of Chemical Constituents to Quantico Creek

Potential Source	Activities Conducted	Potential COPCs
<i>Marine Corps Base</i>		
Site 35 Drum Storage Area	Storage of drum containing Univolt 60 Transformer Oil	PAHs
Site 58 Stained Soil (oily residue)	Unknown	Unknown – possibly PAHs, PCBs?
Site 14 1920's Landfill (Little Creek)	Garbage from Base burned at the site	PAHs, total petroleum hydrocarbons (TPH), pesticides, lead
Site 98 Pesticide Mixing Area (Little Creek)	Mixing area for pesticides applied to the base golf course.	Pesticides, mercury
Storm Drain Outfalls	Drain storm water from parking lots and roof drains, cooling water from base hospital, and hospital incinerator	PAHs, aluminum, copper
<i>Offsite</i>		
Mining Activities	Upstream mining of gold, silver, and pyrite	Metals, especially aluminum, arsenic, cadmium, copper, iron, manganese, and zinc
Potomac River	Influx of water and sediment from Potomac River into Quantico Creek due to tidal action	PCBs, pesticides, PAHs
Possum Point Power Plant	Combustion of coal and oil, discharge of cooling water to Potomac River just upstream of Quantico Creek	PAHs

4.1.2 Fate and Transport

A physical fate and transport diagram for chemical constituents in Quantico Creek is presented in Figure 4-1. Colored lines are used in the diagram to assist the reader in following release mechanisms to impacted media. The primary transport pathway of chemical constituents from the Base to Quantico Creek is through surface water runoff. Surface water transport includes non-point source flow during precipitation events, point source discharges from storm sewer outfalls, and surface water flow from Little Creek discharging to Quantico Creek. Several intermittent stream channels and swales receive surface water runoff from the southern ridge adjacent to the floodplain, as well as, runoff generated from the site. Based on the site's shallow topographic gradient, surface water generated at the site will either infiltrate into the underlying substrate or discharge into Little Creek or Quantico Creek via the intermittent stream channels and swales. Groundwater is expected to flow north to north-northeast, most likely discharging into Little Creek or Quantico Creek.

Once in the creek, the primary redistribution of chemical constituents in sediments are due to resuspension and movement of sediments due to storm conditions. Although no specific flow velocity data is available for Quantico Creek, a low flow velocity is expected in Quantico Creek, as demonstrated by the overall shallow nature of the creek and the fact that there are no clear channels running through the lower portion of the creek. Although tidal action could transport chemical constituents in an upstream direction, data indicate that significant transport in this direction has not occurred. Metals associated with upstream mining activities show decreasing concentrations as one moves downstream, and chemical constituents apparently originating from downstream sources (*i.e.*, PAHs, DDxs) have remained localized in downstream sediments. This indicates upstream tidal transport of sediments is not a significant transport pathway. Chemical constituents that have likely originated from downstream sources (*i.e.*, PAHs, PCBs, DDxs), are expected to remain bound to sediment with little partitioning to the water column due to their relatively insoluble nature and their affinity for organic matter. Data collected in the Potomac River just downstream of the mouth of Quantico Creek as part of the Quantico Watershed Pilot Study do not indicate that chemicals from Quantico Creek are being deposited in the nearshore areas of the Potomac River (Battelle and Neptune and Company, 2001).

Food chain transport to upper trophic levels is considered a significant transport pathway for bioaccumulating organic chemical constituents present in Quantico Creek. PCBs, DDxs, and PAHs in particular are expected to be transferred to humans and upper trophic level ecological receptors through ingestion of food items that have accumulated these constituents from sediments. Although no fish tissue data was collected during this investigation, fish tissues of PCBs, DDxs, and PAHs were estimated by applying sediment to fish bioaccumulation factors recommended by the EPA National Sediment Quality Survey (EPA, 2001).

4.2 Human Health Exposure Scenarios and Pathways

Access to Quantico Creek is via the water is unrestricted to the public, but actual use is limited due to the natural terrain and control of some shoreline areas by the Quantico Marine Corps Base. A recreational land use scenario will be used to evaluate the results of the human health screening assessment. The primary activity for members of the public and Base community along the Base shore of the creek is assumed to be recreational fishing. Potentially complete exposure pathways related to recreational fishing include ingestion of fish, incidental ingestion of creek sediments, and dermal contact with creek sediments. Inhalation of vapors was considered an incomplete exposure pathway since volatile organic chemicals are not present. Ingestion of plant products is judged to be an incomplete exposure pathway because no plant species viable for routine use as food products have been identified in Quantico Creek adjacent to the Base. Given the obstacles to navigation in the creek (extremely shallow nature and the low clearance railroad bridge at the creek mouth), there is not a need to dredge any portion of the creek

4-3

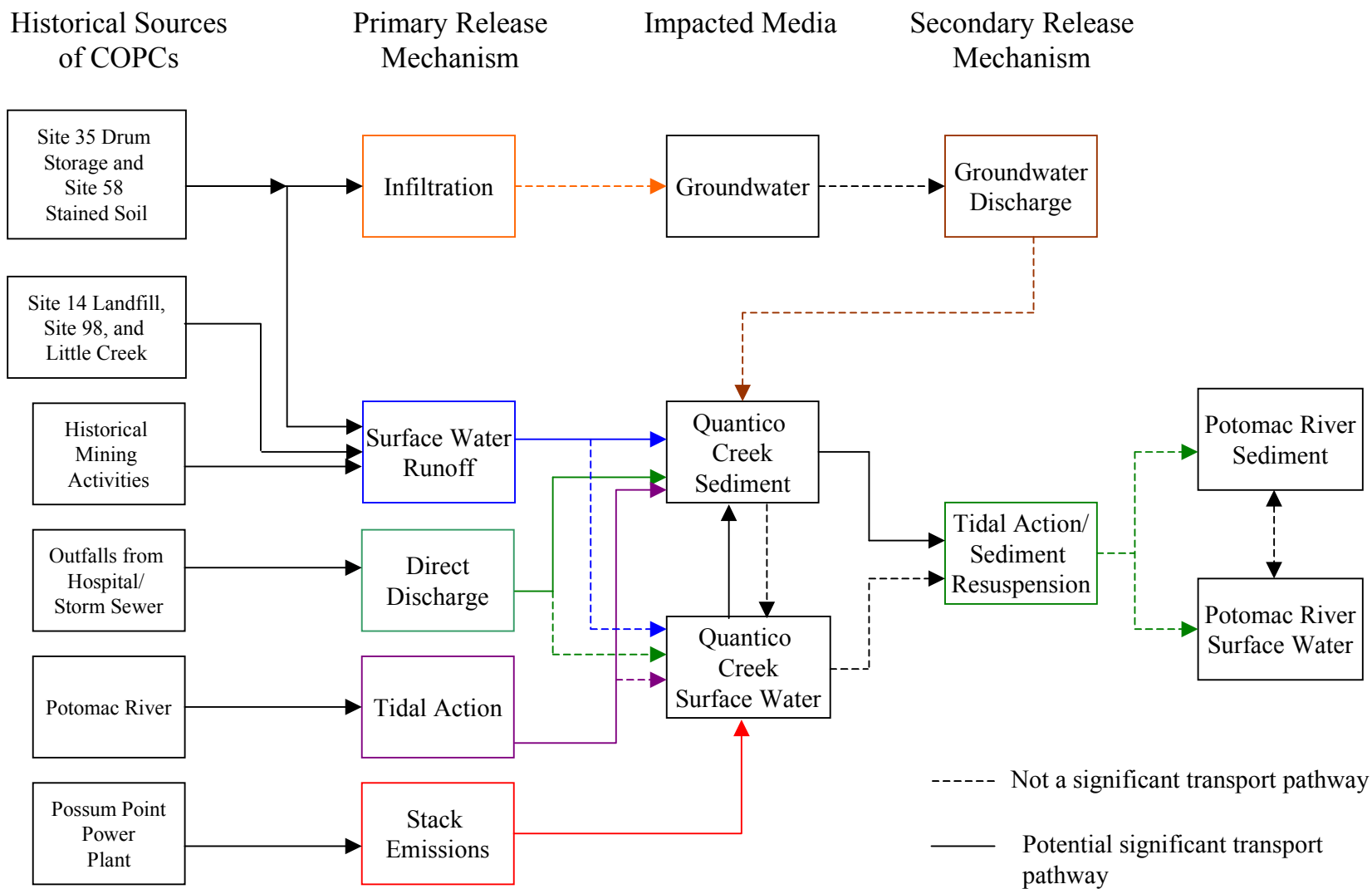


Figure 4-1. Quantico Creek Physical Site Model.

presently or the foreseeable future. As such, there is no need to consider more terrestrially relevant exposure scenarios (residential, occupational) that may be relevant if sediment dredge spoils were used as fill material.

4.3 Ecological Exposure Scenarios and Pathways

The primary exposure of mammals and birds to chemical constituents in Quantico Creek is through ingestion of sediment, and for bioaccumulating compounds, through the ingestion of contaminated prey. Dermal contact is considered a primary exposure pathway for benthic invertebrates residing in the sediment, but is not considered a significant pathway for birds or mammals. Inhalation of vapors was considered an incomplete exposure pathway since volatile organic chemicals were not detected in the sediment. A generalized food web for Quantico Creek is presented in Figure 4-2.

To assess potential risk to piscivorous birds, a screening-level food chain model will be constructed using the great blue heron as a surrogate for piscivorous birds in Quantico Creek. Great blue herons forage in shallow wetland and offshore waters all along the Potomac River and its tributaries. Although great blue herons will travel long distances from the nest to forage, once at a foraging area, they remain in a relatively small area (~1.5 acres). This together with their trophic level status as a top-level piscivore provides a conservative exposure model to evaluate risks. Great blue herons will eat a variety of fish, invertebrates, reptiles, and amphibians, but for the purpose of this screening level risk assessment they are being modeled as strict piscivores. Raccoon will be used as a surrogate for all piscivorous mammals inhabiting Quantico Creek. It is recognized that due to their various diet, modeling the raccoon as a strict piscivore is ecologically unrealistic, but this model is meant to be protective of all aquatic mammals that may inhabit the area (*e.g.*, muskrat). The raccoon is proposed as a surrogate for other omnivorous mammals because standardized exposure parameters are available for the raccoon, and the raccoon is known to occur at the site. The role of each of the proposed screening endpoints in the food web is shown in Figure 4-3. Vertebrate herbivores and omnivores were not considered in this evaluation because upper-level piscivores have a higher exposure to bioaccumulating constituents and therefore are more conservative receptors than the herbivores and omnivores.

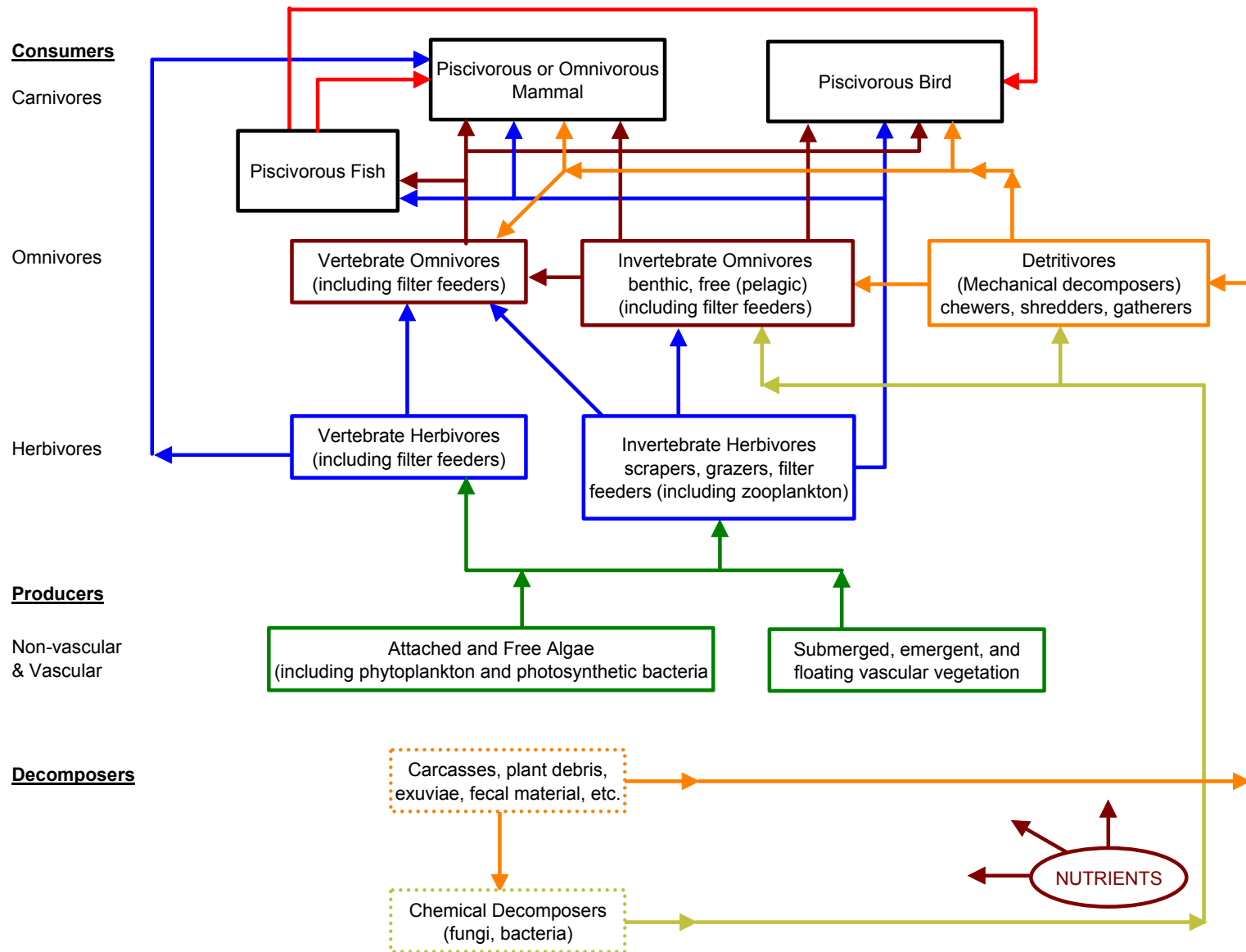


Figure 4-2. Quantico Creek Generalized Aquatic Food Web.

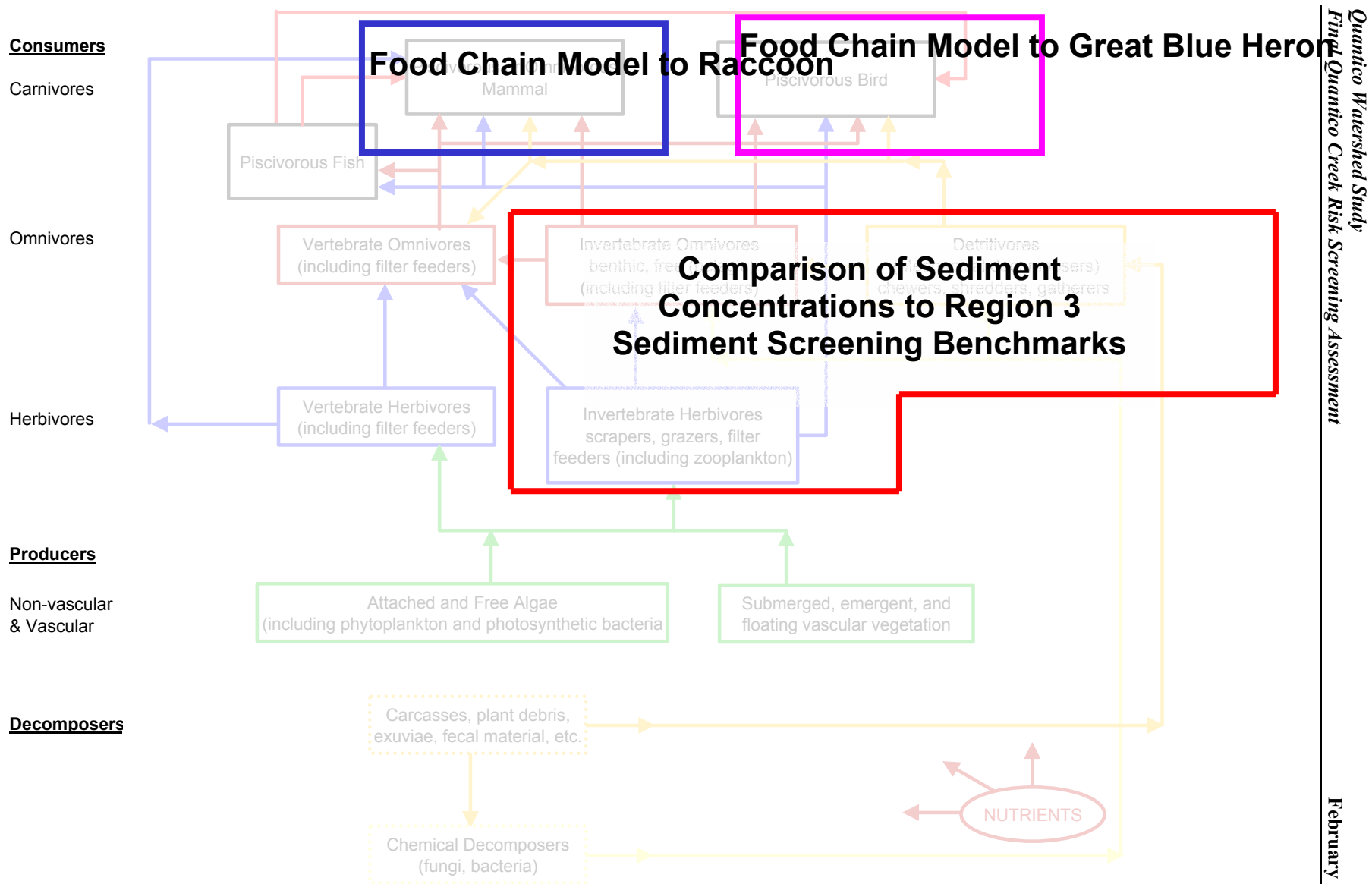


Figure 4-3. Quantico Creek Aquatic Food Web with Screening Endpoints.

5.0 SCREENING-LEVEL HUMAN HEALTH RISK ASSESSMENT

The screening-level human health risk assessment evaluates potential health effects associated with exposure to chemicals in Quantico Creek sediments. Health effects resulting from direct contact with creek sediments (*i.e.*, sediment ingestion or dermal contact) are screened using values that are based on EPA Region 3 residential soil RBCs. Residential RBCs are used as the basis for sediment screening values because applicable sediment screening values are unavailable. The potential for chemical concentrations in sediments to impact human health via a recreational fish ingestion pathway is also evaluated in this screening using biota-sediment accumulation factors (BSAFs) published by U.S. EPA (EPA 2001) and fish tissue RBCs published by EPA Region 3.

Section 5 is presented in three subsections. The protocol for performing the screening assessment, and the assumptions pertaining to the RBCs and BSAFs used in the screening, are described in Section 5.1. A screening evaluation of maximum site chemical concentrations relative to EPA Region 3 RBCs for residential soils and fish ingestion is presented in Section 5.2. An interpretation of the uncertainty in the screening results, and conclusions of the screening assessment, are presented in Section 5.3.

5.1 Human Health Screening Assessment Protocol

The screening protocol used in the human health screening assessment consists of comparison of chemical constituent concentrations in individual site sediment samples to EPA Region 3 RBCs for residential soil and, via use of the BSAFs, to RBCs for fish tissue. Chemicals are not prescreened on the basis of detection status or by comparison to reference area (background) levels prior to comparison with RBCs. However, the results of comparisons of site and background chemical concentrations (Section 3.2) will be included in the uncertainty analysis in Section 5.3.

Eight sediment samples were collected along the southern shoreline of Quantico Creek adjacent to the Quantico Marine Corps Base. Another eight samples were collected along the northern and upstream portions of Quantico Creek to establish background concentrations of chemicals in creek sediments. Laboratory analytical data for these 16 sediment samples are available for 18 metals, 18 individual PAHs, 22 chlorinated pesticides or their derivatives, and PCBs as 7 specific aroclors and as 18 specific congeners. A complete description of sampling and analysis methods and rationale is provided in Section 3.1.

Residential soil and fish tissue RBCs were obtained from the EPA Region 3 RBC table dated April 2, 2002 (EPA Region 3, 2002). These RBCs employ a cancer risk threshold of 10^{-6} and a hazard quotient of one. Because Region 3 RBC values are published for the seven PCB aroclors reported by the analytical laboratory but not for the specific PCB congeners, only the aroclor data were used in this screening assessment. To screen the potential significance of the recreational fish ingestion pathway, BSAFs were used to relate sediment chemical concentrations to possible fish tissue concentrations. These BSAFs were obtained from the draft EPA report, "The Incidence and Severity of Sediment Contamination in Surface Waters of the United States, National Sediment Quality Survey: Second Edition" (EPA 2001).

Analytical detection limit values (*i.e.*, U-qualified or UJ-qualified results) were applied in the screening assessment as one-half of the sample-specific reporting limit. The use of one-half of the reporting limit is consistent with EPA Region 3 direction in, "Guidance on Handling Chemical Concentration Data Near the Detection Limit in Risk Assessments" (EPA Region 3, 1991). In this guidance, EPA Region 3 describes several options for selecting a value for non-detects including use of one-half the detection limit (DL), zero, and a statistical estimate of non-detect values. Following the logic described by EPA Region 3, a value of one-half the DL was selected to represent non-detects in this screening.

Residential soil RBCs were multiplied by ten in this screening assessment prior to use in the screening assessment. This practice is consistent with EPA Region 3 protocol for the use of soil RBCs to screen sediment chemical concentrations (personal communication: Ralph Perona, Neptune and Company, and Alvaro Alvarado, EPA, 6/13/2002). An additional Region 3 protocol discussed in the referenced communication is the use of a hazard quotient of 0.1 (rather than 1) in the screening assessment to account for potential additivity of effects among chemicals whose RBCs are based on noncarcinogenic effects. The RBC values for chemicals whose RBCs are based on noncarcinogenic effects were therefore divided by ten for application in the screening assessment. The derivation of sediment RBCs therefore followed the following steps:

1. identify the chemical-specific residential soil RBC;
2. multiply the RBC by ten to account for the lower anticipated exposure intensity to sediments;
3. determine if the RBC is based on carcinogenic or noncarcinogenic effects; and,
4. for noncarcinogenic effects, an HQ of 0.1 is used to account for potential additive effects among chemicals (*i.e.*, RBC is divided by 10).

In practice, the application of the protocol described in the four steps means that the sediment RBC values tabulated in Table 5-1 for chemicals whose residential soil RBCs are based on carcinogenic effects can be obtained by multiplying the EPA Region 3 residential soil RBC by ten. The sediment RBC values for chemicals whose residential soil RBCs are based on noncarcinogenic effects are identical to the residential soil RBCs published by EPA Region 3. Standard practice in a risk assessment is to use a hazard quotient of 1.0 and address the potential for additive effects among chemicals in a toxicity assessment. However, at the recommendation of the EPA (personal communication: Ralph Perona, Neptune and Company, and Alvaro Alvarado, EPA, 6/13/2002), a hazard quotient of 0.1 is used for the screening and any noncarcinogenic chemicals identified as potentially of concern due to direct contact with sediments will be further evaluated in the uncertainty analysis in Section 5.3.

The protocol of evaluating noncarcinogenic chemicals using one-tenth of the RBC value was also applied to the fish tissue RBC values. Therefore, fish tissue RBCs published by EPA Region 3 for chemicals whose RBCs are based on noncarcinogenic effects were divided by ten prior to use in this screening assessment. Fish tissue RBCs for chemicals whose RBCs are based on carcinogenic effects were not altered.

5.2 Human Health Screening Assessment Results

Table 5-1 provides a comparison of the maximum detected site concentration or one-half the greatest reported site detection limit (whichever is greater) with sediment RBC values. The sediment RBC values were derived from EPA Region 3 residential soil RBCs according to the protocol described in Section 5.1. The tabulated maximum site concentration is also multiplied by a BSAF to calculate a projected maximum concentration in fish tissue. These fish tissue values are compared to fish tissue RBCs derived by EPA Region 3. Maximum concentrations in sediment or fish tissue that exceed an RBC are indicated by the use of bold typeface in Table 5-1.

Table 5-1. Screening of Maximum Sediment Concentrations.

Chemical	Detects	Maximum Conc. ^a	Sediment RBC ^{a,b} (direct contact)	BSAF	Projected Fish Tissue Maximum Conc. ^a	Fish Tissue RBC ^{a,b}
Metals						
Aluminum	8/8	76400	78000	NA	-	140
Antimony	8/8	6.49	31	NA	-	0.054
Arsenic	8/8	13.2	4.3	NA	-	0.0021
Barium	8/8	598	5500	NA	-	9.5
Beryllium	8/8	2.83	160	NA	-	0.27
Cadmium	8/8	2.74	78 ^c	NA	-	0.14 ^c
Chromium	8/8	83.3	230 ^d	NA	-	0.41 ^d
Cobalt	8/8	32.4	1600	NA	-	2.7
Copper	8/8	229	3100	NA	-	5.4
Iron	8/8	45557	23000	NA	-	41
Lead	8/8	122	400 ^e	NA	-	NA
Manganese	8/8	1210	1600 ^f	NA	-	19 ^g
Mercury	8/8	0.364	7.8 ^h	NA	-	0.014 ^h
Nickel	8/8	66.6	1600	NA	-	2.7
Selenium	8/8	3.27	390	NA	-	0.68
Silver	8/8	1.07	390	NA	-	0.68
Thallium	8/8	1.13	5.5	NA	-	0.0095
Zinc	8/8	785	23000	NA	-	41
Pesticides						
Aldrin	3/8	1.95	380	1.8	3.5	0.19
Dieldrin	5/8	4.32	400	1.8	7.8	0.2
Endosulfan I ⁱ	0/8	0.11	4.7E+05 ^j	1.8	0.20	810 ^j
Endosulfan II ⁱ	0/8	0.105	4.7E+05 ^j	1.8	0.19	810 ^j
Endrin ⁱ	0/8	0.095	23000	1.8	0.17	41
Heptachlor ⁱ	0/8	0.09	1400	1.8	0.16	0.7
Heptachlor Epoxide ⁱ	0/8	0.08	700	1.8	0.14	0.35
Methoxychlor ⁱ	0/8	0.12	3.9E+05	1.8	0.22	680
Mirex ⁱ	0/8	0.085	16000	1.31	0.11	27
Toxaphene ⁱ	0/8	23.96	5800	1.8	43	2.9
DDD-2,4	8/8	23.52	27000 ^k	0.28 ^l	6.6	13 ^k
DDE-2,4	5/8	2.38	19000 ^k	7.7 ^l	18	9.3 ^k
DDT-2,4 ⁱ	0/8	0.135	19000 ^k	1.67 ^l	0.23	9.3 ^k
DDD-4,4	8/8	81.91	27000 ^k	0.28	23	13 ^k
DDE-4,4	8/8	41.69	19000 ^k	7.7	321	9.3 ^k
DDT-4,4	5/8	22.4	19000 ^k	1.67	37	9.3 ^k
alpha-Chlordane	8/8	2.66	18000 ^m	4.77	13	9 ^m
alpha-BHC ⁱ (HCH)	0/8	0.055	1000	1.8	0.10	0.5
beta-BHC ⁱ (HCH)	0/8	0.12	3500	1.8	0.22	1.8
delta-BHC ⁱ (HCH)	0/8	0.095	1000 ⁿ	1.8	0.17	0.5 ⁿ
gamma-Chlordane	1/8	3.56	18000 ^m	2.22	7.9	9 ^m
gamma-BHC (HCH)	6/8	0.3	4900	1.8	0.54	2.4

Table 5-1. Screening of Maximum Sediment Concentrations (con't).

Chemical	Detects	Maximum Conc. ^a	Sediment RBC ^a (direct contact)	BSAF	Projected Fish Tissue Maximum Conc. ^a	Fish Tissue RBC ^a
PAHs					-	
2-Methylnaphthalene	8/8	37.46	1.6E+06	0.29 ^o	11	2700
Acenaphthene	8/8	24.78	4.7E+06	0.29	7.2	8100
Acenaphthylene	8/8	5.32	4.7E+06 ^p	0.29 ^p	1.5	8100 ^p
Anthracene	8/8	40.43	2.3E+07	0.29	12	41000
Benz(a)anthracene	8/8	297.5	8700	0.29	86	4.3
Benzo(a)pyrene	8/8	247.5	870	0.29	72	0.43
Benzo(b)fluoranthene	8/8	278.1	8700	0.29	81	4.3
Benzo(g,h,i)perylene	8/8	139.9	2.3E+06 ^q	0.29 ^q	41	4100 ^q
Benzo(k)fluoranthene	8/8	267.8	87000	0.29	78	43
Chrysene	8/8	356.5	8.7E+05	0.29	103	430
Dibenz(a,h)anthracene	8/8	36.81	870	0.29	11	0.43
Fluoranthene	8/8	554	3.1E+06	0.29	161	5400
Fluorene	8/8	38.25	3.1E+06	0.29	11	5400
Indeno(1,2,3-c,d)pyrene	8/8	152.1	8700	0.29	44	4.3
Naphthalene	6/8	49.1	1.6E+06	0.29	14	2700
Perylene	8/8	829.2	2.3E+06 ^q	0.29 ^q	240	4100 ^q
Phenanthrene	8/8	203	2.3E+06 ^q	0.29 ^q	59	4100 ^q
Pyrene	8/8	525.6	2.3E+06	0.29	152	4100
Aroclors						
Aroclor-1016 ⁱ	0/8	12	5500	1.85 ^r	22	45
Aroclor-1221 ⁱ	0/8	12	3200	1.85 ^r	22	1.6
Aroclor-1232 ⁱ	0/8	12	3200	1.85 ^r	22	1.6
Aroclor-1242 ⁱ	0/8	12	3200	1.85 ^r	22	1.6
Aroclor-1248 ⁱ	0/8	12	3200	1.85 ^r	22	1.6
Aroclor-1254 ⁱ	0/8	12	3200	1.85 ^r	22	1.6
Aroclor-1260	7/8	34.24	3200	1.85 ^r	63	1.6

NA: not available

^aMetals values in mg/kg, organic chemical values in µg/kg.

^bRBC values are modified as described in Section 5.1.

^cCadmium toxicity value based on administration in food.

^dChromium as chromium VI.

^eLead value is for play areas of a residential yard (*Identification of Dangerous Levels of Lead, Final Rule*. FR Vol. 66 No. 4, January 5, 2001, U.S. EPA)

^fManganese sediment value based on exposure via soil ingestion.

^gManganese fish tissue value based on exposure via food.

^hMercury as methylmercury.

ⁱThe tabulated maximum value is ½ of the highest reported detection limit.

^jAs endosulfan; not isomer specific.

^kDDD, DDE, and DDT RBC values are not isomer specific.

^lValue for the 4,4- isomer used as a surrogate.

^mAs chlordane; not isomer specific.

ⁿalpha-HCH, the isomer with the most restrictive RBC value, used as a surrogate.

^oNaphthalene used as a surrogate.

^pAcenaphthene used as a surrogate.

^qPyrene used as a surrogate.

^rAs PCBs, not aroclor specific.

Two chemicals, arsenic and iron, have maximum concentrations that exceed the sediment RBC for direct contact by factors of approximately three and two, respectively. When screening for potential impacts via fish ingestion using BSAF values, eight pesticides (including four isomers of DDT or its breakdown products), six PAHs, and six of the seven PCB aroclors had maximum projected fish tissue concentrations exceeding fish tissue RBC values. BSAF values were not available for metals. Even though the maximum sediment concentrations for every metal exceed the respective fish tissue RBC, metals concentrations in site sediments were not statistically significantly different from concentrations observed in sediments representative of background conditions (see Section 3). The results of the numerical comparisons indicate relatively little potential for health impacts via direct contact with sediment but a potential for health impacts via fish ingestion. The results of the numerical comparisons will be evaluated in Section 5.3.

Four chemicals (acenaphthylene, benzo(g,h,i)perylene, perylene, and phenanthrene) did not have RBC values in the Region 3 table. In accordance with EPA guidance (EPA 1989, Section 8.4), the potential consequences of the lack of toxicological criteria for these five chemicals are evaluated in this assessment. The potential health risks related to these chemicals are discussed by comparison of site concentrations to surrogate chemical RBCs.

Acenaphthylene and acenaphthene are virtually identical PAHs. Both are three-ring compounds where two of the rings are six-carbon and the third is five-carbon. The only difference between the compounds is that acenaphthylene has an additional carbon double bond in the five-carbon ring structure. Benzo(g,h,i)perylene, a six-ring PAH, consists of two “nested” phenanthrene molecules each containing three rings. Benzo(g,h,i)perylene and phenanthrene share the similar trait of containing a “bay” region (an area on the molecule where carcinogenically reactive epoxides might form) without evidence of carcinogenicity in the available animal data. Perylene is a five-ring PAH that also contains “bay” regions. The four-ring PAH pyrene was selected as a toxicity surrogate for these PAHs as it is most similar in structure among the PAHs that do not exhibit carcinogenicity. Among the PAHs that are not considered potential human carcinogens but have EPA reference dose values, pyrene has the lowest oral reference dose and hence is a protective surrogate from a toxicological perspective.

Chemical concentrations in eight sediment samples collected in Quantico Creek upgradient of the Base were compared with concentrations in the eight samples collected adjacent to the base (downgradient). Four separate statistical tests were employed to determine if concentrations of inorganic chemicals, PAHs, and total PCBs were different between upgradient and downgradient locations. Among the pesticides, only detection frequencies for total DDXs (DDD, DDE, and DDT) and alpha-chlordane were adequate for all four comparisons. Two of the statistical tests were applied to gamma-BHC and dieldrin. As discussed in Section 3.2, chemicals that were determined to be present in greater concentrations in the downgradient samples were total PCBs, total DDXs, several PAHs, and dieldrin. As evident in the bubble plots for PAHs, there is also evidence that PAH concentrations in the downgradient data set are higher in sediments near the mouth of Quantico Creek than in the samples collected further upstream adjacent to the base. This may be indicative of one or more local sources of petroleum hydrocarbons in this area or additional sources transported from the Potomac River that may be influencing the downgradient Quantico Creek sediments.

5.3 Human Health Screening Assessment Uncertainty Analysis

Maximum site sediment concentrations of arsenic and iron were the only values that exceeded the sediment RBC screening values for direct contact. Concentrations of these metals in downgradient sediment samples were not statistically different from concentrations in the upgradient samples. This indicates that the concentrations of these metals in Quantico Creek sediments near the Marine Corps Base are not elevated with respect to ambient conditions. Additionally, exposure intensity associated

with the residential land use scenario used for calculating the soil RBCs (350 days/year) is likely to be far greater than actual recreational exposure to creek sediments adjacent to the Base. The factor of ten used to adjust the soil RBC for sediments still results in an exposure intensity of 35 days/year, with an implicit assumption that sediment ingestion rates during the visit are equivalent to the daily rates used in the residential calculations. Yet maximum sediment concentrations of arsenic and iron exceeded the RBC values by factors of only three and two, respectively. For these reasons, the results of the numerical comparisons of site sediment data and sediment RBCs indicate that there is little or no potential for unacceptable chemical hazards due to direct contact with sediments.

The screening results for iron in particular do not suggest a potential health concern. The sediment RBC value for iron incorporates a protective hazard quotient of 0.1 to account for potentially additive effects. However, no other noncarcinogenic chemicals were identified as potentially of concern via either direct contact or fish ingestion pathways. Additionally, the toxicity value for iron used in the calculation of the EPA Region 3 soil RBC is a provisional value based upon the upper range of normal dietary iron intake rather than a specific toxic insult.

As described in Section 5.2, concentrations of several PAHs, pesticides, and PCB aroclors were identified as potentially of concern via a fish ingestion pathway. Although BSAF values were not available for metals, a comparison of metal sediment concentrations and fish tissue RBCs suggests that the fish ingestion pathway may also be of concern for metals because sediment concentrations sometimes exceed fish tissue RBCs by factors of several hundred. Because exposure via direct sediment contact was determined to be of negligible concern, the remainder of this uncertainty analysis will focus on potential human health effects from chemicals in sediments via the fish ingestion pathway.

The principal source of uncertainty related to the screening assessment results for the fish ingestion pathway is uncertainty in the accuracy and applicability of the BSAF values that convert sediment concentrations to fish tissue concentrations. There is also uncertainty in the results of the statistical comparison of upgradient and downgradient chemical concentrations. Because this is a screening-level assessment, the EPA Region 3 RBCs are used as definitive health-protective benchmarks; uncertainties and protective biases relating to assumptions underlying the fish tissue RBCs are not explored. Uncertainties related to the use of surrogate chemicals, described in Section 5.2, are likely to be small because sediment and fish tissue concentrations of acenaphthylene, benzo(g,h,i)perylene, perylene, and phenanthrene are low relative to their respective RBC screening values.

The BSAF values used in the screening assessment for PAHs, pesticides, and PCBs fall within a range of 0.29 for PAHs to 7.7 for DDE isomers. The BSAF for PCBs and most pesticides was approximately two. These BSAF values were developed based on studies of the ratios of sediment and fish tissue chemical concentrations and so are considered applicable for this screening assessment. There is always a degree of uncertainty in applying a single ratio such as a BSAF for converting soil or sediment concentrations to tissue concentrations because such ratios are expected to change with the chemical concentration in the soil or sediment. In particular, applying a ratio developed using a relatively low soil or sediment chemical concentration to a high chemical concentration is likely to cause an overestimation of the resulting tissue concentration (Bechtel, 1998). However, the relatively low BSAF values and the fact that site sediment chemical concentrations are also relatively low suggests that this source of uncertainty has not resulted in a large bias in the predicted fish tissue concentrations.

Among the chemicals with maximum predicted fish tissue concentrations above RBC levels, only PCBs, DDXs, and dieldrin were determined to be present in higher concentrations in downgradient sediments. The individual PAHs that were present in higher concentrations in downgradient sediments did not include any of the six carcinogenic PAHs highlighted in Table 5-1. Statistical p-values for these carcinogenic PAHs ranged from 0.251 to 0.318, well above the common criterion of statistical

significance (0.05). Although metal sediment concentrations were often considerably higher than associated fish tissue RBCs, no metals were present in higher concentrations in downgradient sediments compared to upgradient sediments. This is true even for metals typically of concern due to their bioaccumulative nature, such as mercury. Because of the lack of differences in metals concentrations between site sediments and background sediments, no metals were evaluated through the fish ingestion pathway. The results of the upgradient and downgradient chemical concentration comparisons therefore suggests that PCBs, DDXs, and dieldrin are the only chemicals associated with potential health effects that may be related to operations at Quantico Marine Corps Base.

The screening results indicate that PCBs, DDXs, and dieldrin may have a downstream source in Quantico Creek and may also be of human health concern via a fish ingestion pathway. Fish consumption advisories issued by the Maryland Department of the Environment (MDE) for the region of the Potomac River that includes the Quantico Embayment and Quantico Creek already address PCBs and dieldrin. With respect to Quantico Creek, this screening suggests that DDXs in sediments may also be of potential human health concern via a fish ingestion exposure pathway. Given the limited size of Quantico Creek, however, it is uncertain whether the DDX concentrations measured in sediments would, in fact, result in the predicted fish tissue concentrations. Such factors as the range and feeding characteristics of fish also play a role in establishing actual fish tissue concentrations. It is more likely that fish tissue concentrations of DDXs, dieldrin, and PCBs in fish that might be caught in Quantico Creek are based on sediment chemical concentrations both within the creek and in Potomac River generally.

6.0 SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT AND REFINEMENT

A screening-level ecological risk assessment and refinement was conducted for Quantico Creek sediments to determine if Base operations have potentially impacted creek sediments. This follows Environmental Protection Agency (EPA) Superfund Ecological Risk Assessment Guidance (EPA, 1997), Navy ERA guidelines (Navy, 1999), and EFACHES ecological screening and refinement protocol (EFACHES, 2001). Steps 1 and 2 of the 8-step EPA Superfund guidance encompass the screening portion of the ERA. The screening refinement for Quantico Creek encompasses Step 3a of the EPA guidance, which allows for the refinement of the chemicals of potential ecological concern (COPECs) by applying more site-specific information to the exposure assessment. The screening-level risk assessment uses conservative exposure assumptions to determine if site chemicals pose a risk to ecological receptors and warrants any actions.

6.1 Screening Protocol

The problem formulation step of the screening risk assessment is presented in Section 4.3. This process identified the following pathways and receptors for consideration in the screening risk assessment:

- Sediment contact and ingestion by benthic invertebrates
- Ingestion of contaminated food by piscivorous mammals
- Ingestion of contaminated prey by piscivorous birds

The screening exposure estimate and risk characterization was conducted in two parts. The first part involved comparing maximum concentrations of constituents in sediment to conservative sediment screening benchmarks accepted by EPA Region 3 (EPA 1995, Buchman, 1998). These benchmarks are considered to be protective of benthic (sediment-dwelling) organisms. The methodologies and results of this comparison are presented in Section 6.2.1.

The second part of the screening consisted of modeling food chain exposures to the great blue heron and raccoon as surrogates for piscivorous birds and mammals, respectively, in Quantico Creek. In this step, daily doses of chemical constituents were calculated based upon maximum observed sediment concentrations and bioaccumulation factors (BAFs) obtained from the literature. The calculated doses were compared to available toxicity reference values (TRVs) for birds and mammals. The methodologies and results of the food chain modeling are presented in Section 6.2.2. Constituents that failed either of these two screening steps were carried forward to the refinement step of the screening-level ecological risk assessment (EPA Step 3A), which is discussed in Section 6.3. In the refinement step, background conditions in Quantico Creek were taken into consideration, and exposure point concentrations were modified to provide more realistic exposure estimates that reflect sediment exposures across the site.

6.2 Screening-Level Risk Characterization

6.2.1 Screening-Level Risks to Benthic Invertebrates

A hazard quotient (HQ) for each chemical constituent was derived by dividing the maximum concentration by the sediment screening benchmark. For constituents not detected, the maximum reported detection limit was used to calculate the HQ. The comparison of Base sediment concentrations to sediment screening benchmarks is presented in Table 6-1.

Table 6-1. Comparison of Chemical Concentrations in Site Sediments to Region 3 Ecological Sediment Screening Benchmarks.

Analyte	Freq. of Detect	Maximum	Minimum	Region 3 Screening Value	HQ	COPC
Metals (mg/kg dry wt)						
Aluminum	8/8	74300	39600	No benchmark	na	Yes
Antimony	8/8	6.49	0.548	150	0.04	No
Arsenic	8/8	13.2	5.41	8.2	1.6	Yes
Barium	8/8	598	520	No benchmark	na	Yes
Beryllium	8/8	2.83	1.69	No benchmark	na	Yes
Cadmium	8/8	2.74	0.456	1.2	2.3	Yes
Cobalt	8/8	32.4	16.2	No benchmark	na	Yes
Chromium	8/8	83.3	47.7	260	0.32	No
Copper	8/8	229	46.1	34	6.7	Yes
Iron	8/8	45557	23963	No benchmark	na	Yes
Lead	8/8	122	45.9	46.7	2.6	Yes
Mercury	8/8	0.364	0.117	0.15	2.4	Yes
Manganese	8/8	1210	604	No benchmark	na	Yes
Nickel	8/8	66.6	24.6	20.9	3.2	Yes
Selenium	8/8	3.27	0.668	0.7	4.7	Yes
Silver	8/8	1.07	0.325	1	1.07	Yes
Thallium	8/8	1.13	0.565	No benchmark	na	Yes
Zinc	8/8	785	134	150	5.2	Yes
Pesticides (ug/kg dry wt)						
Aldrin	3/8	1.95	[0.09]*	9.5	0.21	No
Dieldrin	5/8	4.32	[0.17]	0.02	216	Yes
Endosulfan I	0/8	[0.22]	[0.11]	No benchmark (0.93 proposed)	(0.24)	No
Endosulfan II	0/8	[0.21]	[0.11]	No benchmark (0.93 proposed)	(0.23)	No
Endrin	0/8	[0.19]	[0.1]	No benchmark	na	No
Heptachlor	0/8	[0.18]	[0.09]	0.3	0.6	No
Heptachlor Epoxide	0/8	[0.16]	[0.08]	No benchmark	na	No
Methoxychlor	0/8	[0.24]	[0.12]	No benchmark (29.58 proposed)	(0.008)	No
Mirex	0/8	[0.17]	[0.09]	No benchmark (1.55 proposed)	(0.11)	No
Toxaphene	0/8	[47.91]	[24.3]	No benchmark	na	No
2,4'-DDD	8/8	23.52	0.68	No benchmark	na	Yes
2,4'-DDE	5/8	2.38	[0.18]	No benchmark	na	Yes
2,4'-DDT	0/8	[0.27]	[0.14]	No benchmark	na	No
4,4'-DDD	8/8	81.91	1.96	16	5.1	Yes
4,4'-DDE	8/8	41.69	3.47	2.2	18.9	Yes
4,4'-DDT	5/8	22.4	[0.13]	1.58	14.2	Yes

Table 6-1. Comparison of Chemical Concentrations in Site Sediments to Region 3 Ecological Sediment Screening Benchmarks (con't.).

Analyte	Freq. of Detect	Maximum	Minimum	Region 3 Screening Value	HQ	COPC
alpha-Chlordane	8/8	2.66	0.21	0.5	5.3	Yes
alpha-BHC	0/8	[0.11]	[0.06]	No benchmark (0.6 proposed)	(0.18)	No
beta-BHC	0/8	[0.24]	[0.12]	No benchmark (0.5 proposed)	(0.48)	No
delta-BHC	0/8	[0.19]	[0.1]	No benchmark	na	No
gamma-Chlordane	1/8	3.56	[0.08]	0.5	7.12	Yes
gamma-BHC	6/8	0.3	[0.07]	0.32	0.94	No
PCBs (ug/kg dry wt)						
Total PCBs	8/8	65.16	27.84	22.7	2.9	Yes
PAHs (ug/kg dry wt)						
2-Methylnaphthalene	8/8	37.46	7.54	70	0.54	No
Acenaphthene	8/8	24.78	1.67	16	1.5	Yes
Acenaphthylene	8/8	5.32	0.47	44	0.12	No
Anthracene	8/8	40.43	2.93	85.3	0.47	No
Fluorene	8/8	38.25	5.85	19	2.01	Yes
Naphthalene	6/8	49.1	[7.87]	160	0.31	No
Phenanthrene	8/8	203.04	17.94	240	0.85	No
Benzo(a)anthracene	8/8	297.46	13.48	261	1.14	Yes
Benzo(a)pyrene	8/8	247.47	13.06	430	0.58	No
Benzo(b)fluoranthene	8/8	278.06	21.34	3200	0.09	No
Benzo(g,h,i)perylene	8/8	139.93	9.54	670	0.21	No
Benzo(k)fluoranthene	8/8	267.83	18.81	1800	0.15	No
Chrysene	8/8	356.46	25.67	384	0.93	No
Dibenz(a,h)anthracene	8/8	36.81	1.69	63.4	0.58	No
Fluoranthene	8/8	554.05	43.52	600	0.92	No
Indeno(1,2,3-cd)pyrene	8/8	152.06	7.9	600	0.25	No
Perylene	8/8	829.16	180.7	No benchmark	na	Yes
Pyrene	8/8	525.6	39.4	665	0.79	No
Total PAHs	8/8	3478	411.5	4022	0.86	No

*Values in brackets represent detection limits

HQ = Hazard quotient

COPC = chemical of potential concern

NA = not applicable

All metals with the exception of antimony and chromium had hazard quotients greater than 1. Pesticides with sediment HQs greater than 1 were dieldrin, alpha-chlordane, gamma-chlordane, and DDT and its metabolites. Specific sediment screening benchmarks for the 2,4-isomers of the DDx compounds have not been developed, but since they are chemically similar to the 4,4-isomers, the 2,4-isomers are expected to exhibit similar toxicities. Since concentrations of the 2,4-DDx isomers are correlated with concentrations of the 4,4-DDx isomers, and concentrations of the 2,4-isomers in Quantico Creek are always less than concentrations of the 4,4-isomers at the same sampling location, it is assumed that any risk decision based on the 4,4-isomers also encompasses the 2,4-isomers of DDx. Aldrin was detected in three of eight site samples, and gamma-BHC in six of eight site samples, but all at concentrations less than sediment screening benchmarks, and therefore they are not considered COPCs for benthic organisms. No other pesticides were detected at the site. Of the PAH compounds, acenaphthene, fluorene, and benzo(a)anthracene had HQs greater than 1. No screening benchmark was available for perylene, and it is also considered a COPC for benthic organisms. To account for possible additive toxic effects of PAH compounds, an HQ was calculated for total PAHs. Since the total PAH HQ was less than one, only the four individual PAH compounds identified above are retained for further evaluation in screening refinement. Total PCBs were calculated by adding the 18 NOAA NS&T congeners and multiplying by two. The HQ for total PCBs exceeded one, therefore they are considered a COPC based upon potential risk to benthic organisms.

Any constituents with HQs greater than 1 were carried forward to the screening refinement. Constituents with HQs less than 1 were not considered to be chemicals of potential concern (COPCs) to benthic organisms. Constituents without ecological screening benchmarks were carried forward to the screening refinement step if they were detected in at least one sample.

6.2.2 Screening Evaluation of Risk to Upper Trophic Level Receptors

Risk to upper trophic level receptors was assessed by constructing conservative food-chain models to estimate daily dose to receptors and comparing that dose to piscivorous avian and mammalian TRVs. Risk to upper trophic levels were evaluated for all chemical constituents that were detected in at least one site sample and independent of the risk evaluation to benthic organisms (Section 6.2.1).

Exposure parameters for the food chain receptors and the sources and rationale for the chosen parameters are presented in Tables 6-2 and 6-3. Conservative exposure factors were used in this screening-level assessment. Site use factors (SUFs) for all receptors were set equal to one, indicating that all foraging occurs adjacent to the Quantico Marine Corps Base in Quantico Creek. When published ingestion rates were available for receptors, the maximum published ingestion rate was used. When published ingestion rates were not available, ingestion rates were calculated using the appropriate ingestion equations from the EPA Wildlife Exposure Factors Handbook (EPA, 1993). Sediment to fish BAFs used recommended values published in the U.S. EPA National Sediment Quality Survey (EPA, 2001). No recommended sediment to fish BAFs were published for metals, since metals bioaccumulation is largely dependent on such factors as the chemical form of the metal present, the pH of the sediment, the hardness of the overlying water, and the amount of acid volatile sulfates present in the sediment. To be conservative, concentrations of metals in fish were assumed to be equal to the concentrations in the sediment.

Table 6-2. Hazard Quotient Calculations for Great Blue Heron Screening-level Food Chain Model.

Exposure Parameter	Source	Abbreviation	Unit	Values for Great Blue Heron
Body weight ^a	1 (average of all reported adult wts.)	BW	kg	2.34
Ingestion rate ^b	1	IR	kg/kg/day	0.18
Daily ingestion ^c	calculated	DI _{total}	kg/day	0.42
Percent of sediment in diet ^d	2 ^e	%Sediment	percent	2
Daily sediment ingestion ^f	calculated	DI _{sed}	kg/day	0.008
Percent fish in diet ^g	3	%Fish	percent	100
Daily fish ingestion ^h	calculated	DI _{fish}	kg/day	0.42
Foraging range ⁱ	1 (minimum reported)	FR	ac	1.5
Site use factor (max of 1) ^j	conservative value for screening	SUF	unitless	1

Sources:

1. EPA, 1993.
 2. Based on reported values of blue-winged teal and ring-necked duck, from Beyer, W. N., E. E. Connor, and S. Gerould, 1994. (see footnote d)
 3. Zeiner, D. C., W. F. Laudenslayer Jr., K. E. Mayer, and M. White, 1988–1990. Online at <http://www.dfg.ca.gov/whdab/cwhr/cawildlife.html>.
- ^a Body weight: Mean of all reported adult weights. With only three data points, the mean body weight will provide the most unbiased estimate of the average adult.
- ^b Ingestion rate: This was a single value provided in EPA, 1993 (1). This value is supported by information provided in “daily ingestion”, below.
- ^c Daily ingestion: This value was calculated as $DI_{total} \text{ (kg/day)} = BW \text{ (kg)} \cdot IR$. This finding is supported by the calculation of the daily ingestion of foodstuffs by wading birds (Kushlan equation, p. 2-4 of EPA, 1993 [1]) which yields a result of 0.41 kg/day. Results are in keeping with the assumptions regarding the mean body weight.
- ^d Percent of sediment in diet: Based on the study of blue-winged teal and ring-necked duck by Beyer *et al.*, 1994 (2). No information was available for great blue heron. The blue-winged teal and ring-necked duck values were deemed most appropriate since these ducks, like the great blue heron, gather food items out of the sediment and therefore likely have a similar percentage of incidental sediment ingestion.
- ^e No information was available for great blue heron. The blue-winged teal and ring-necked duck values were deemed most appropriate since these ducks, like the great blue heron, gather food items (invertebrates and plant material) out of the sediment and therefore likely have a similar percentage of incidental sediment ingestion.
- ^f Daily sediment ingestion: Calculated as $\% \text{ sediment} \cdot DI_{total} = DI_{sed}$.
- ^g Percent fish in diet: Zeiner *et al.*, 1988–1990 (3) estimates that the great blue heron’s diet is approximately 75% fish and 25% other flesh (including invertebrates). However for the purposes of this model, the heron is being modeled as a strict piscivore
- ^h Daily fish ingestion: Calculated as $\% \text{ fish} \cdot DI_{total} = DI_{fish}$.
- ⁱ Foraging range: Although great blue herons may travel up to 25 mile from nesting areas to forage, once in a foraging area, EPA (1993) (1) reports feeding territories as small as 1.5 ac;
- ^j Site use factor: Ecological Risk Assessment Guidance for Superfund (EPA, 1997) recommends a site use factor of 1 for all receptors in a screening-level assessment.

Table 6-3. Exposure Parameters for Raccoon.

Exposure Parameter	Source	Abbreviation	Unit	Values for Raccoon
Body weight ^a	1 (median of all reported adult wts.)	BW	kg	6.0
Ingestion rate ^b	calculated	IR	kg/kg/day	0.2
Daily ingestion ^c	1 (calculated)	DI _{total}	kg/day	0.3
Percent of sediment in diet ^d	2	%Sediment	percent	9.4
Daily sediment ingestion ^e	calculated	DI _{sed}	kg/day	0.11
Percent fish in diet ^f	1,3,4 (estimated)	%Fish	percent	100
Daily fish ingestion ^g	calculated	DI _{fish}	kg/day	0.3
Foraging range ^h	1	FR	ac	39
Site use factor (max of 1) ⁱ	conservative value for screening	SUF	unitless	1

Sources:

1. Allometry based on equation 3-7, from EPA, 1993.
 2. Beyer, W. N., E. E. Connor, and S. Gerould, 1994.
 3. Zeiner, D. C., W. F. Laudenslayer Jr., K. E. Mayer, and M. White, 1988–1990. Online at <http://www.dfg.ca.gov/whdab/cwhr/cawildlife.html>.
 4. USFS, 1996. Online at <http://www.fs.fed.us/database/feis/> [Updated March 12, 1998].
- ^a Body weight: Body weight was calculated as the median adult weight reported in EPA, 1993 (1). The mean and median were calculated, and the median was used, as it was slightly greater (6.0 vs. 5.8); the median is a reasonable expectation for the average of a sampled population.
- ^b Ingestion rate: This value was back calculated from the daily ingestion and the body weight ($IR = DI_{total} / BW$).
- ^c Daily ingestion: This value was calculated as $DI \text{ (kg/day)} = 0.0687 \cdot BW \text{ (kg)}^{0.822}$ dry weight (equation 3-7 for all mammals, EPA, 1993 [1]). This equation is adapted from Nagy, 1987: Nagy, K. A. 1987. "Field metabolic rate and food requirement scaling in mammals and birds." *Ecological Monographs* 57 (2): 111-128.
- ^d Percent of sediment in diet: Based on study of raccoons by Beyer *et al.*, 1994 (2).
- ^e Daily sediment ingestion: Calculated on the basis of the reported percent sediment ingestion in diet and the daily ingestion ($\% \text{sediment} \cdot DI_{total} = DI_{sed}$).
- ^f Percent fish in diet: All sources (EPA, 1993 [1]; Zeiner *et al.*, 1988–1990 [3]; USFS, 1996 [5]) indicate that the diet of raccoons is highly variable and opportunistically based. However for the purposes of this screening assessment, the raccoons diet is assumed to be entirely fish. This assumption is to make the model protective of all piscivores in Quantico Creek.
- ^g Daily fish ingestion: Calculated as $\% \text{fish} \cdot DI_{total} = DI_{fish}$.
- ^h Foraging range: Raccoons have widely varying home and foraging ranges. These can depend strongly on sex, the areas topography, habitat availability, and seasonable variability of foodstuffs (EPA, 1993 [1]; Zeiner *et al.*, 1988–1990 [3]; USFS, 1996 [5]). However, home ranges for local island populations off of the coast of Georgia are reported to be quite small (relatively); these small home ranges serve well as a lower interval size estimate of foraging range, as raccoons, albeit gregarious, are otherwise defensive of limited foraging resources and will defend small territories.
- ⁱ Site use factor: Ecological Risk Assessment Guidance for Superfund (EPA, 1997) recommends a site use factor of 1 for all receptors in a screening-level assessment.

The equation used in calculating dose to the upper trophic level receptors is presented in the equation below.

$$Dose = \frac{(C_{sed} * DI_{sed}) + (C_{sed} * BAF * DI_{fish}) * SUF}{BW}$$

where:

Dose is the dose rate measured in milligram contaminant per kilogram receptor body weight per day (mg/kg/day);

C_{sed} is the maximum concentration of chemical in sediment measured in milligram contaminant per kilogram of sediment (mg/kg);

DI_{sed} is the daily ingestion of sediment measured in kilograms sediment per day (kg/day);

DI_{fish} is the daily ingestion of fish measured in kilograms fish per day (kg/day);

BAF is the sediment to fish bioaccumulation factor from EPA, 2001 (unitless);

SUF is the receptor's site use factor. For a screening-level ERA, the *SUF* is assumed equal to 1.0, meaning that the receptor acquires 100% of its foodstuffs from Quantico Creek adjacent to the Quantico Marine Corps Base.

BW is the organism's body weight in kilograms.

The comparison of calculated doses for the great blue heron and raccoon to TRVs taken from the published literature are presented in Tables 6-4 and 6-5, respectively. Specific information on the sources of the TRVs and the basis for their selection is presented in Appendix B. Two hazard quotients (HQs) were calculated for each chemical for each food chain receptor. The HQ1 represents the maximum calculated dose divided by a chronic No Observed Adverse Effects Level (NOAEL) TRV. This was the primary HQ value upon which the decision to retain a chemical constituent for the screening refinement step or dismiss from further consideration was based. The HQ2 represents the maximum dose divided by a chronic Lowest Observed Adverse Effects (LOAEL) TRV. This value is presented as a means of bounding the potential risk associated with chemical constituents that have HQ1 values exceeding 1. HQ values exceeding 1 are highlighted in the tables. Nine metals (aluminum, barium, chromium, cobalt, lead, manganese, mercury, selenium, zinc) and one organic constituent (DDE) had HQ1 values greater than 1 for the great blue heron, indicating potential risk to piscivorous birds. HQ2 values for the heron were exceeded for the same metals except cobalt, which does not have a LOAEL-based TRV, manganese, and selenium. HQ2 values for DDE were less than 1 for the heron. Maximum doses of 7 metals exceeded HQ1 values for the raccoon, indicating potential risk to piscivorous mammals. Five of the metals (arsenic, Chromium, cobalt, copper, and thallium) had HQ1 values exceeding 1, but HQ2 values less than 1 for raccoon. The remaining two metals (aluminum and barium) had both HQ1 and HQ2 values greater than 1 for raccoon. No organic constituents had HQ values greater than one in the raccoon food chain model, and therefore would not pose a risk to piscivorous mammals.

Constituents with HQ1 values greater than one in either of the food chain models were retained for further evaluation in the screening refinement step. A summary of chemical constituents failing the initial screening assessment is presented in Table 6-6.

6.3 Refinement of Screening-level Risk Assessment

All of the chemicals listed in Table 6-6 were evaluated further in the screening refinement step of the screening-level ecological risk assessment. The screening refinement step for Quantico Creek consisted of two parts. In the first part of the refinement, background conditions in Quantico Creek were considered to assess whether potential risk posed by constituents in sediments adjacent to the Quantico

Table 6-4. Hazard Quotient Calculations for Great Blue Heron Screening-level Food Chain Model.

Analyte	Max Sed Conc. (mg/kg)	Sediment to Fish BAF	Maximum Fish Conc. (mg/kg)	Max Dose (mg/kg-d)	High Avian TRV (mg/kg-d)	Low Avian TRV (mg/kg-d)	HQ2 (Max Dose/High TRV)	HQ1 (Max Dose/Low TRV)
4,4'-DDD	0.082	0.28	0.023	0.004	NA	0.009	NA	0.473
4,4'-DDE	0.042	7.7	0.321	0.058	0.6	0.009	0.096	6.22
4,4'-DDT	0.022	1.67	0.037	0.007	1.5	0.009	0.005	0.731
Aluminum	74300	1	74300	13613	1097	110	12.41	124
Arsenic	13.2	1	13.2	2.42	7.38	2.46	0.327	0.983
Barium	598	1	598	109	41.7	20.8	2.62	5.27
Beryllium	2.83	1	2.83	0.519	NA	NA	NA	NA
Cadmium	2.74	1	2.74	0.502	20.3	1.45	0.025	0.346
Chromium	83.3	1	83.3	15.26	5	1	3.05	15.26
Cobalt	32.4	1	32.4	5.94	NA	0.02	NA	297
Copper	229	1	229	41.96	61.7	47	0.680	0.893
Iron	45560	1	45560	8347	NA	NA	NA	NA
Lead	122	1	122	22.35	11.3	1.13	1.98	19.8
Manganese	1210	1	1210	221.7	997	99.7	0.222	2.22
Mercury	0.364	1	0.364	0.067	0.064	0.006	1.04	10.42
Nickel	66.6	1	66.6	12.2	107	77.4	0.114	0.158
Selenium	3.27	1	3.27	0.599	1	0.5	0.599	1.19
Silver	1.07	1	1.07	0.196	54.4	5.44	0.004	0.036
Thallium	1.13	1	1.13	0.207	NA	NA	NA	NA
Zinc	785	1	785	143.8	131	14.5	1.10	9.92
Benzo(a)anthracene	0.298	0.29	0.086	0.017	20	2	8E-04	0.008
Benzo(a)pyrene	0.248	0.29	0.071	0.014	20	2	7E-04	0.007
Benzo(b)fluoranthene	0.278	0.29	0.081	0.015	20	2	8E-04	0.008
Benzo(g,h,i)perylene	0.140	0.29	0.041	0.008	20	2	4E-04	0.004
Benzo(k)fluoranthene	0.268	0.29	0.078	0.015	20	2	7E-04	0.007
Chrysene	0.357	0.29	0.103	0.020	20	2	0.001	0.01

Table 6-4. Hazard Quotient Calculations for Great Blue Heron Screening-level Food Chain Model (con't).

Analyte	Max Sed Conc. (mg/kg)	Sediment to Fish BAF	Maximum Fish Conc. (mg/kg)	Max Dose (mg/kg-d)	High Avian TRV (mg/kg-d)	Low Avian TRV (mg/kg-d)	HQ2 (Max Dose/High TRV)	HQ1 (Max Dose/Low TRV)
Dibenzo(a,h)anthracene	0.037	0.29	0.011	0.002	20	2	1E-04	0.001
Fluoranthene	0.554	0.29	0.161	0.031	20	2	0.002	0.015
Indeno(1,2,3-cd)pyrene	0.152	0.29	0.044	0.008	20	2	4E-04	0.004
Perylene	0.829	0.29	0.240	0.003	20	2	1E-04	0.001
Pyrene	0.526	0.29	0.152	0.029	20	2	0.001	0.015
2-methylnaphthalene	0.038	0.29	0.011	0.002	20	2	1E-04	0.001
Acenaphthene	0.025	0.29	0.007	0.001	20	2	6.8E-05	7E-04
Acenaphthylene	0.005	0.29	0.002	3E-04	20	2	1.45E-05	1E-04
Anthracene	0.040	0.29	0.011	0.002	20	2	1E-04	0.001
Fluorene	0.038	0.29	0.011	0.002	20	2	1E-04	0.001
Naphthalene	0.049	0.29	0.014	0.003	20	2	1E-04	0.001
Phenanthrene	0.203	0.29	0.059	0.011	20	2	6E-04	0.006
Total PCB	0.065	1.85	0.121	0.022	1.8	0.18	0.012	0.121
Aldrin	0.002	1.8	0.003	6E-04	NA	NA	NA	NA
Alpha-chlordane	0.003	4.77	0.013	0.002	10.7	2.14	2E-04	0.001
Dieldrin	0.004	1.8	0.078	0.001	0.77	0.077	0.002	0.018
Gamma-BHC (lindane)	3E-04	1.8	5E-04	9.8E-05	20	2	4.9E-06	4.9E-05
Gamma-chlordane	0.0036	2.22	0.008	0.001	10.7	2.1	1E-04	7E-04

Table 6-5. Hazard Quotient Calculations for Raccoon Screening-level Food Chain Model.

Analyte	Maximum Sediment Conc. (mg/kg)	Sediment to Fish BAF	Maximum Fish Conc. (mg/kg)	Max Dose (mg/kg-d)	High Mammal TRV (mg/kg-d)	Low Mammal TRV (mg/kg-d)	HQ2 (Max Dose/High TRV)	HQ1 (Max Dose/Low TRV)
4,4'-DDD	0.082	0.28	0.023	0.002	16	0.83	9.73E-05	0.002
4,4'-DDE	0.042	7.7	0.321	0.016	16	0.83	0.001	0.020
4,4'-DDT	0.022	1.67	0.037	0.002	16	0.83	0.0001	0.002
Aluminum	74300	1	74300	4086	19.3	1.93	211.8	2118
Arsenic	13.2	1	13.2	0.726	1.26	0.126	0.58	5.76
Barium	598	1	598	32.89	19.8	5.1	1.66	6.45
Beryllium	2.83	1	2.83	0.16	6.6	0.66	0.024	0.236
Cadmium	2.74	1	2.74	0.15	10	1	0.015	0.151
Chromium	83.3	1	83.3	4.58	13.4	3.3	0.342	1.39
Cobalt	32.4	1	32.4	1.78	12	1.2	0.148	1.48
Copper	229	1	229	12.59	15.1	11.7	0.834	1.08
Iron	45600	1	45600	2506	NA	NA	NA	NA
Lead	122	1	122	6.71	80	8	0.084	0.839
Manganese	1210	1	1210	66.55	284	88	0.234	0.756
Mercury	0.364	1	0.364	0.02	0.16	0.032	0.125	0.626
Nickel	66.6	1	66.6	3.66	80	40	0.046	0.092
Selenium	3.27	1	3.27	0.180	0.33	0.2	0.545	0.899
Silver	1.07	1	1.07	0.059	18.1	1.81	0.003	0.033
Thallium	1.13	1	1.13	0.062	0.074	0.007	0.840	8.40
Zinc	785	1	785	43.17	320	160	0.135	0.270
Benzo(a)anthracene	0.297	0.29	0.086	0.006	1.7	0.17	0.003	0.034
Benzo(a)pyrene	0.247	0.29	0.072	0.005	10	1.31	0.0004	0.004
Benzo(b)fluoranthene	0.278	0.29	0.081	0.005	40	4	0.0001	0.001
Benzo(g,h,i)perylene	0.140	0.29	0.041	0.003	72	7.2	3.79E-05	0.0004
Benzo(k)fluoranthene	0.268	0.29	0.078	0.005	72	7.2	7.25E-05	0.0007
Chrysene	0.356	0.29	0.103	0.007	1.7	0.17	0.004	0.041

Table 6-5. Hazard Quotient Calculations for Raccoon Screening-level Food Chain Model (con't).

Analyte	Maximum Sediment Conc. (mg/kg)	Sediment to Fish BAF	Maximum Fish Conc. (mg/kg)	Max Dose (mg/kg-d)	High Mammal TRV (mg/kg-d)	Low Mammal TRV (mg/kg-d)	HQ2 (Max Dose/High TRV)	HQ1 (Max Dose/Low TRV)
Dibenzo(a,h)anthracene	0.037	0.29	0.011	0.0007	13.3	1.33	5.4E-05	0.00054
Fluoranthene	0.554	0.29	0.161	0.011	25	12.5	0.0004	0.0009
Indeno(1,2,3-cd)pyrene	0.152	0.29	0.044	0.003	72	7.2	4.12E-05	0.0004
Perylene	0.829	0.29	0.240	NA	NA	NA	NA	NA
Pyrene	0.53	0.29	0.152	0.010	12.5	7.5	0.0008	0.001
2-methylnaphthalene	0.037	0.29	0.011	0.0007	25	2.5	2.92E-05	0.0003
Acenaphthene	0.025	0.29	0.007	0.0005	35	17.5	1.38E-05	2.76E-05
Acenaphthylene	0.005	0.29	0.002	0.0001	700	70	1.48E-07	1.48E-06
Anthracene	0.040	0.29	0.012	0.0008	1000	100	7.88E-07	7.88E-06
Fluorene	0.038	0.29	0.011	0.0007	1250	125	5.97E-07	5.97E-06
Naphthalene	0.049	0.29	0.014	0.001	150	50	6.38E-06	1.91E-05
Phenanthrene	0.203	0.29	0.059	0.004	514	51.4	7.7E-06	7.7E-05
Total PCB	0.065	1.85	0.121	0.006	0.69	0.14	0.009	0.045
Aldrin	0.002	1.8	0.004	0.0002	1	0.2	0.0002	0.0009
Alpha-chlordane	0.003	4.77	0.013	0.0006	9.2	4.58	7.04E-05	0.0001
Dieldrin	0.004	1.8	0.008	2.16E-05	0.2	0.02	0.0001	0.001
Gamma-BHC (lindane)	3E-04	1.8	5E-04	2.85E-05	3.75	0.05	7.6E-06	0.0006
Gamma-chlordane	0.004	2.22	0.008	0.0004	9.2	4.58	4.49E-05	9.02E-05

Table 6-6. Summary of Initial COPCs for Each Line of Evidence (HQs>1 in Bold).

Analyte	Sediment Screening Benchmark HQ	Great Blue Heron Food Chain Model HQ1	Raccoon Food Chain Model HQ1
Aluminum	NA	124	2118
Arsenic	1.6	0.98	5.76
Barium	NA	5.27	6.45
Beryllium	NA	NA	0.151
Cadmium	2.3	0.35	1.39
Chromium	0.32	15.3	1.48
Cobalt	NA	297	1.08
Copper	6.7	0.89	NA
Iron	NA	NA	0.839
Lead	2.6	19.8	0.626
Mercury	2.4	10.4	0.756
Manganese	NA	2.2	0.092
Nickel	3.2	0.16	0.899
Selenium	4.7	1.2	2118
Silver	1.1	0.04	0.033
Thallium	NA	NA	8.40
Zinc	5.2	9.9	0.270
Dieldrin	216	0.02	0.001
4,4-DDD	5.1	0.48	0.002
4,4-DDE	18.9	6.2	0.020
4,4-DDT	14.2	0.73	0.002
Total PCBs	2.9	0.12	0.045
Alpha-Chlordane	5.3	0.001	0.001
Gamma-Chlordane	7.1	7.0E-4	9.02E-05
Acenaphthene	1.5	7.0E-4	2.76E-05
Fluorene	2.0	0.001	5.97E-06
Benzo(a)anthracene	1.1	0.008	0.034
Perylene	NA	0.001	NA

Marine Corps Base was different from potential risk posed by sediments not influenced by the Base. Results from the background tests presented in Section 3 were used to determine if potential site risk was different from background risk. If site concentrations of a constituent were not significantly different from background concentrations, then that constituent was no longer considered a site COPC. If site concentrations of a constituent were significantly higher than the background concentrations, then those constituents were evaluated to see if the 95% upper confidence limit (UCL) site concentration was greater than sediment screening benchmarks, and/or if food chain doses calculated using the 95% UCL site concentrations exceeded TRVs.

If the 95% UCL site concentrations/doses were not greater than screening benchmarks/TRVs, the constituent was eliminated as a COPC. If site concentrations were different from background concentrations AND the 95% UCL concentrations exceeded screening benchmarks or resulted in food chain doses greater than TRVs, the constituent was considered a site COPC.

6.3.1 Evaluation of Quantico Creek Background Conditions

As discussed in Section 3 (Table 3-4), there were no statistically significant differences in any of the distribution of metals in Quantico Creek compared to background conditions. This analysis suggests that most metals in the creek are the result of upstream sources, most likely the historical mining operations. Site concentrations were not different from background, and therefore, risks associated with exposure to metals are not different from background. As a result, metals were eliminated from further consideration as COPCs in Base sediments in Quantico Creek.

Four PAHs (acenaphthene, fluorene, benzo(a)anthracene, and perylene) failed screening comparisons of maximum site concentrations to sediment screening benchmarks. Acenaphthene and fluorene were statistically significantly higher in site sediments than in background sediments, while there was no statistical difference between site and background concentrations of benzo(a)anthracene or perylene. As a result, acenaphthene and fluorene were carried forward to the second step of screening refinement, while benzo(a)anthracene and perylene were not considered further as COPCs.

Concentrations of total PCBs and several pesticides also exceeded Region 3 sediment screening benchmarks. Of the pesticides, background comparisons could not be conducted for dieldrin or gamma-chlordane because the Gehan and t-test tests require at least 50% detects in each of the areas. However, since both of these constituents were detected more often in site sediments than in background sediments, they appear in a qualitative sense to be higher at the site. These two pesticides are carried forward to the second step of screening refinement. Of the remaining pesticides that had concentrations above sediment benchmarks, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT were significantly elevated in site sediments compared to background sediments, and therefore are retained for further evaluation in the screening refinement process. Alpha-chlordane was not significantly elevated compared to background sediments and is not considered further as a COPC. Total PCBs concentrations in site sediments were significantly greater than in background sediments and are retained for further evaluation.

6.3.2 Evaluation of Exposure Point Concentrations

Eight constituents were retained as potential COPCs in Base sediments after the screening refinement comparison to Quantico Creek background conditions. The second step of screening refinement involves calculating screening hazard quotients using the 95% UCL on the mean concentrations as an estimator of site exposure point concentrations. The 95% UCL site concentrations of the eight remaining constituents were compared to the sediment screening benchmarks accepted by EPA Region 3. Of those remaining constituents, only 4,4'-DDE failed food chain model comparisons (for great blue heron), so it is the only constituent for which food chain dose was recalculated using the 95% UCL concentration in place of the

maximum concentration. Results of the screening refinement using 95% UCL exposure point concentrations are presented in Table 6-7. The 95% UCL sediment concentrations of all remaining constituents exceeded Region 3 sediment screening thresholds and these constituents remain as COPCs. Use of the 95% UCL in calculation of 4,4'-DDE dose to great blue heron resulted in reduction of the HQ1 value from 6.2 to 4.3. The HQ2, based upon the LOAEL TRV, is less than 1. Since the HQ1 value is still greater than 1 using the 95% UCL in place of the maximum, 4,4'-DDE cannot be eliminated as a potential COPC to top-level piscivorous birds feeding in Quantico Creek.

Table 6-7. Screening Refinement Using 95% UCL Exposure Point Concentrations.

Analyte	95% UCL Site Exposure Point Concentration	Region 3 Sediment Screening Benchmark	95% UCL Food Chain Dose to Heron	Low Avian TRV	Refined HQ1	Retain as COPC?
Acenaphthene	24.6 µg/kg	16 µg/kg				Yes
Fluorene	25.1 µg/kg	19 µg/kg				Yes
Dieldrin	1.8 µg/kg	0.02 µg/kg				Yes
4,4-DDD	81.9 ^(a) µg/kg	16 µg/kg				Yes
4,4-DDE	29.1 µg/kg	2.2 µg/kg	0.040 mg/kg-d	0.0093 mg/kg-d	4.3	Yes
4,4-DDT	12.0 µg/kg	1.58 µg/kg				Yes
Gamma-Chlordane	3.4 µg/kg	0.5 µg/kg				Yes
Total PCBs	48 µg/kg	22.7 µg/kg				Yes

(a) 95% UCL is higher than the maximum, so maximum was retained as exposure point concentration

6.4 Uncertainty Discussion

Five chlorinated pesticides, two PAH compounds, and total PCBs remain as COPCs in Base sediments in Quantico Creek following the ecological risk screening and refinement. A number of uncertainties are inherent in any screening level risk assessment. The most immediate of these is the conservative nature of screening thresholds and the NOAEL-based TRVs. The screening benchmarks for the remaining COPCs are Effects Range-Low (ER-L) values developed by Long, *et al.*, (1995). These values represent the 10th percentile of published effects levels for each of the above chemical constituents. Due to community differences across habitats and geographic areas, species present at the site being evaluated may be significantly more or less tolerant to the chemical constituent than the species that serve as the basis for the ER-Ls. Long *et al.* also identified the 50th percentile of published effects levels, which he termed the effects range-median (ER-M), for these chemical constituents. By definition, it is more likely that an adverse effect will be noted when chemical concentrations are at ER-M levels than at their ER-L levels. All of the observed concentrations of gamma-chlordane, dieldrin, acenaphthene, fluorene, and total PCBs were below the respective ER-Ms for those constituents. Maximum and mean exposure point concentrations of the 4,4-DDx compounds exceeded their respective ER-Ms.

Likewise, there is uncertainty in the identification of NOAEL and LOAEL-based TRVs for the food chain model comparisons. This is illustrated very well in the nearly two orders of magnitude difference between the NOAEL-based and LOAEL-based avian TRVs for 4,4-DDE. In theory, the NOAEL and LOAEL should be very close together, as there is likely a very small range of concentrations where effects start to be noticed. In reality, the true NOAEL (and the true LOAEL) for DDE likely lie

somewhere between the published NOAEL of 0.0093 mg/kg-d and the published LOAEL of 0.6 mg/kg-d. These published NOAEL and LOAEL values are in part artifacts of the experimental design of the studies that produced them. Since the 4,4-DDE doses to great blue heron fell between the published NOAEL and LOAEL, it is uncertain how closely the doses fall to the actual NOAEL and LOAEL values.

Another source of uncertainty is the conservative nature of the exposure assumptions used in the screening-level assessment. The food chain exposures assume that the piscivorous birds and mammals are foraging entirely within the area of concern, and that their prey has spent all of its life within the area of concern, thereby maximizing exposure to the chemical constituents present. In theory, an individual heron or raccoon could gather all of its prey from the site area, but in reality raccoons, herons and other piscivorous animals range widely in their pursuit of prey items. Foraging areas may vary on a daily basis based on the availability of prey. Fish are mobile organisms and are unlikely to gather body burdens of chemical constituents that are reflective of point concentrations. It is also unlikely that any animal that inhabits Quantico Creek is entirely piscivorous. Raccoons and herons also ingest a variety of invertebrates, reptiles, amphibians, small mammals, and in the case of raccoons, plant material. Even mammals that are often considered to be largely piscivorous, such as mink, have diets that vary geographically and seasonally, with fish sometimes comprising less than 10% of the diet (EPA 1993).

Another primary uncertainty deals with the bioavailability of constituents in sediment. The screening-level assessment assumes 100% bioavailability of chemical constituents in sediment. Bioavailability of organic constituents is often dependent upon physico-chemical properties of site sediments, including the amount of total organic carbon present. Chemical constituents are almost never 100% bioavailable unless they are in dissolved form, but there are no “rule of thumb” estimates of bioavailability that can be applied to the pesticides remaining as COPCs in Quantico Creek. Nillson and Bjorkland (2002) showed that up to 65% of PCBs in test sediments were extractable under the mildest of extraction conditions, indicating that they may have been readily bioavailable. Assuming 65% bioavailability of PCBs in Quantico Creek sediments would still result in failing comparison to sediment screening benchmarks.

Given the uncertainties associated with the derivation of the screening benchmarks, NOAELs and LOAELs, it becomes difficult to ascertain how much of a risk is posed by the relatively moderate levels of pesticides and PAHs present in Quantico Creek, especially since all but 4,4'-DDE have been shown not to be a risk to top-level piscivorous birds and mammals at the site. This difficulty is compounded by the fact that there is no discernible point source of pesticides or PAHs to Quantico Creek. Sediment sampling conducted by TtNUS in Little Creek downstream of the Site 14 Landfill and the golf course indicate that Little Creek is not a continuing source of pesticides, PAHs, or PCBs to Quantico Creek, and none of the historical operations adjacent to Quantico Creek indicate a source of pesticides that was present beyond that used for residential pest control. Additionally, certain pesticides (*i.e.* dieldrin) and PCBs have been recognized as regional issues in the Potomac River, which cannot be discounted as a source of these constituents in Quantico Creek. As illustrated in the bubble plots in Appendix A, PCB concentrations were remarkably consistent throughout the majority of Quantico Creek, with concentrations all along the south shore similar to those observed in the two reference locations located along the north shore. Only the cluster of reference locations adjacent to the far upstream wetland area showed markedly lower concentrations of PCBs. Given the lack of an operational source of PCBs from the Marine Corps Base to Quantico Creek, it is unlikely that the similar concentrations noted throughout much of the creek originated from Base activities. Acenaphthene and fluorene are ubiquitous environmental contaminants and their source to Quantico Creek cannot be pinpointed with certainty. Potential sources include runoff from Base parking lots and roof drains, as well as non-Base sources such as the railroad bridge and the Possum Point Power Plant. Given the low magnitude of exceedances of sediment screening benchmarks, the fact that concentrations of total PAHs do not exceed total PAH benchmarks, and that no PAHs fail screening level food chain models, it is unlikely that acenaphthene and fluorene pose risks to ecological receptors in Quantico Creek.

7.0 CONCLUSIONS

This section presents the conclusions of the screening-level human health and ecological risk assessments for Quantico Creek.

7.1 Conclusions of the Screening-Level Human Health Risk Assessment

The results of the screening-level human health risk assessment found that arsenic and iron were the only constituents in Quantico Creek sediments adjacent to the Quantico Marine Corps Base that exceeded the sediment RBC screening values for direct contact to humans. Concentrations of these metals in downgradient sediment samples were not statistically different from concentrations in the upgradient samples, indicating that the concentrations of these metals in Quantico Creek sediments near the Base are not elevated with respect to ambient conditions. Given that the exposure intensity associated with the residential land use scenario used for calculating the soil RBCs (350 days/year) is likely to be far greater than any potential recreational exposure to creek sediments, and that maximum sediment concentrations of arsenic and iron exceeded the RBC values by factors of only three and two, respectively, the results of the numerical comparisons of site sediment data and EPA Region 3 RBCs indicate that there is little or no potential for unacceptable chemical hazards due to direct contact with sediments.

Concentrations of several PAHs, pesticides, and PCB aroclors were identified as potentially of concern via a fish ingestion pathway based upon evaluation of sediment to fish BSAFs. Although comparison of sediment metal concentrations and fish tissue RBCs suggests that the fish ingestion pathway may also be of concern for metals, metals were not identified as Base related COPCs for fish ingestion because metals concentrations adjacent to the Base were not significantly different from upstream reference concentrations. Indeed as noted in Section 2, concentrations of most metals in Quantico Creek originate from sources, likely past mining operations, unrelated to Base operations. The results of the comparisons of site chemical concentrations to Quantico Creek background conditions suggest that PCBs, DDx's, and dieldrin are the only chemicals associated with potential fish ingestion related health effects that may possibly be related to releases from the Base. Fish consumption advisories have previously been issued for the region of the Potomac River that includes Quantico Creek for PCBs and dieldrin, and for Quantico Creek itself for PCBs. These advisories recognize a regional problem for these constituents and are intended as guidelines to limit fish consumption. This screening suggests that DDx's in sediments may also be of potential human health concern via a fish ingestion exposure pathway. Given the limited size of Quantico Creek and the limited aerial distribution of elevated levels of DDx's, it is uncertain whether the DDx concentrations measured in Quantico Creek sediments would, in fact, result in the predicted fish tissue concentrations. It is more likely that fish tissue concentrations of DDx's, dieldrin, and PCBs in fish that might be caught in Quantico Creek are based on sediment chemical concentrations found throughout the creek as well as exposures from the Potomac River.

7.2 Conclusions of the Ecological Screening-Level Risk Assessment

Twenty-seven chemical constituents (16 metals, 6 pesticides, 4 PAHs, and total PCBs) had maximum chemical concentrations that exceed EPA Region 3 sediment screening benchmarks. In addition, 12 metals and one pesticide had HQ1 values exceeding 1 in at least one of the food chain exposure models. All of these constituents were carried forward to the ecological screening refinement step.

In the ecological screening refinement, site concentrations of chemical constituents were first evaluated in the context of Quantico Creek ambient, or background conditions. The sixteen remaining metals were eliminated from further consideration as site COPCs, because metals concentrations adjacent to the Base were not significantly different from upstream reference/background concentrations, and available information indicates that the majority of the metals originated from upstream (non-Base related) sources,

in particular historical mining operations located in Prince William Forest Park. Site concentrations of alpha chlordane were not significantly different from upstream reference area concentrations in Quantico Creek, and alpha-chlordane was not retained as a COPC. The 4,4'-DDx compounds all had site concentrations statistically higher than in upstream reference sediments. Background comparisons could not be conducted for dieldrin or gamma-chlordane because they were not detected in at least 50% of the samples from each area, but qualitatively site concentrations of both these constituents appeared higher than background conditions. Dieldrin, gamma-chlordane and the 4,4'-DDx compounds were retained for evaluation of exposure point concentrations. PCBs were also retained for further evaluation because of statistically significant higher concentrations at the site in comparison to the reference areas. Of the remaining PAHs, benzo(a)anthracene, and perylene were eliminated from consideration as COPCs, and acenaphthene and fluorene were retained for further evaluation based upon the background comparisons.

Chemicals not eliminated in the screening process or through evaluation of background conditions were the 4,4'-DDx compounds, dieldrin, gamma-chlordane, total PCBs, acenaphthene, and fluorene. These constituents were next evaluated to determine if their 95% UCL site exposure point concentrations exceeded Region 3 sediment screening benchmarks, and in the case of 4,4'-DDE, whether use of 95% UCL exposure point concentrations in sediment and fish resulted in food chain dose exceeding TRVs. The 95% UCL exposure points of all remaining constituents exceeded sediment screening benchmarks. Food chain doses to great blue heron using 95% UCL concentrations of 4,4'-DDE were approximately 30% lower than maximum doses, but still resulted in HQ1 values exceeding 1 (HQ1 = 4.3).

The screening-level ecological risk assessment and refinement identified the following chemical constituents as COPCs in Base sediments in Quantico Creek: acenaphthene, fluorene, gamma-chlordane, dieldrin, the 4,4'-DDxs, and total PCBs. Of these, only the DDx's had concentrations in site sediments exceeding ER-M thresholds. Given the uncertainties associated with conservative screening benchmarks and estimates of bioavailability of the chemicals in creek sediments, it is difficult to ascertain how much of a risk is posed by pesticides and the two PAHs in Quantico Creek. This is especially true since all but 4,4'-DDE have been shown not to be a risk to top-level piscivorous birds and mammals at the site. This difficulty is compounded by the fact that there is no discernible point source of these pesticides to Quantico Creek from Base or non-Base sources. Sediment sampling conducted by TtNUS in Little Creek downstream of the Site 14 Landfill and the golf course indicate that Little Creek is not a continuing source of pesticides, PAHs, or PCBs to Quantico Creek. Additional samples on the Potomac River upstream of Quantico Creek are being collected as part of the Quantico Embayment Post IRA Study in the fall of 2002, and may provide additional information on regional conditions in the Potomac River that may impact Quantico Creek.

The human health and ecological screening assessments both indicate that there is a potential for risk from PCBs, DDx's, and dieldrin in Quantico Creek. In addition, the ecological screening assessment identified potential risk to benthic fauna from gamma-chlordane, acenaphthene, and fluorene, although potential risk from those constituents is limited in aerial extent. Currently, no known sources of these constituents posing potential risks to human health or ecological receptors have been identified along Quantico Creek from any Base activities.

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